Accidents in Mines

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ACCIDENTS IN MINES

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THEIR CAUSES AND PREVENTION

BY

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TO

JOHN TAYLOR

OF EARSDON

WHOSE CONSTANT CARE OF THOSE EMPLOYED UNDER HIM IN MINES

IS RECOGNISED BY ALL WHO KNOW HIM

THIS BOOK

IS GRATEFULLY DEDICATED

PREFACE.

It was originally intended that the matter in this book should form the subject of a Paper to be read before the Mining Institute, at Newcastle-on-Tyne; the question, however, could not be thus treated without either discussing it in the form of a series of Papers or by omitting some of the less frequent sources of accident.

I have endeavoured, by collecting all the information into one volume, to bring before the public, as seen by those who are engaged professionally as mining engineers, the subject of the number of lives lost in working coal, and the sources of accident which might be prevented.

It may be fairly asked (1) whether the principles of Davy's lamp hold good when the atmospheric pressure is as great as it is in the deep coal mines; and (2) what effect the vibrating waves of sound may have on the flame within the lamp when the lamp is surrounded by an explosive mixture of gas,

such as fire-damp. I am of opinion myself that in the solution of these two problems lies the secret of explosion after shot-firing.

In treating the question of blowers of gas, such as are met with in the Wigan district, especially in the Arley Seam, I have endeavoured to bring the effect of water under the notice of young mining engineers, since this particular phenomenon is often ignored. Seldom does a month pass in which we are not reminded of the risks which accompany coal-mining by some occurrence such as explosion attended with loss of life; and the letters of correspondents in the newspapers are often more calculated to mislead than to throw any real light on the subject. It must be remembered that the question of ventilation is at present passing through a transition state: the Vacuum Fan has replaced the Upcast Furnace. This invention, deserving as it does the greatest praise, has occupied the attention of all professional men, and the two points of which we have spoken have been disregarded.

With respect to the chapter devoted to 'gob-fire,' or spontaneous combustion in the coal-seam, I have also introduced the question of fire in coal-laden ships, and a careful perusal of the accompanying tables will serve to show that the atmosphere of a tropical climate, generally both close and damp, is

sometimes artificially reproduced in the return airways of a coal mine, and the effect on the coal is the same. The proper disposal of waste-heaps and small coal should form one of the most constant cares of the colliery manager, and in this work will be found the whole chemical process of decomposition carefully set forth for his information.

The use of gunpowder in fiery seams is now constantly discussed in Mining Institutes, and we have had ample proof that it should be discontinued, and holing and bringing down the coal by wedges substituted.

My main object, therefore, in writing this work has been to endeavour to put the *true* causes of accident before the public, hoping that by so doing the engineering skill and genius of the country that has produced Davy, Stephenson, Faraday, and Whitworth may be brought to bear on the subject.

In conclusion I cannot, perhaps, do better than quote a line I found written in an original copy of Plowden's Report, date 1616—

Opta optima, expecta pessima, fer quæcunque.

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ACCIDENTS IN MINES.

CHAPTER I.

THE USES OF THE BAROMETER AND THERMOMETER IN COAL MINES.

Explosions and other accidents may be often traced to the fact that the miner, or duly appointed person in the mine, does not pay sufficient attention to the readings of the barometer in the pit. This instrument is as certain a monitor of gas in the mine as it is of storm above ground. The readings given by the barometer and thermometer at the pit bottom, compared with those given by a duplicate set of the above instruments at bank—*i.e.* at the surface—give those in charge of the pit timely warning that goaves, stopped out gob-fires, old waste workings, and other parts of the seam in which gas is known to exist, are in a dangerous state; this state is owing to the sudden decrease of atmospheric pressure on the area of the surfaces of the workings, and therefore a sudden or gradual evolution of gas may at any time be expected to take place.

Many explosions that have occurred in our coal

mines are to be traced to the neglect of such indications. A writer in the 'Times' some time ago (1875) maintained that the barometer would not indicate the presence of carbonic acid gas, and was therefore an instrument worthless to mining engineers. This statement is erroneous, for supposing we have two barometers previously adjusted to one another, the one placed in atmospheric air, and the other in carbonic acid gas, the barometers being on the same level, then clearly the pressure of the heavier gas will be greater than that of the lighter, the resistance, if any, in the Torricellian vacuum of each instrument being precisely the same. The barometer is thus constituted a balance, and fulfils distinctly its original, and most important, function. In a coal mine the barometer might not indicate the presence of carbonic acid gas, but it does not therefore follow that the instrument is worthless, for it will indicate the probability of the existence of fire-damp. With a safety lamp we are able to localise the gas and test its composition; we merely want to be told that we must do so, and this is precisely what the barometer does. It is from such statements as appeared in the 'Times,' in the letter of which we are speaking, that misconceptions arise, and young mining engineers commit blunders which frequently result in loss of life or limb.

As early as the year 1850, attention was paid to the barometer and its indications, and we find Mr. J. T. Wodehouse substituting for the words, *fair*,

rain, stormy, the following rules, which were to be observed by those in charge of the ventilating furnaces at the bottom of the up-cast shaft, viz., '*fire slow,*' '*fire moderate,*' '*fire heavy.*'

The Mines Regulation Act requires that a barometer shall be placed in a conspicuous position near the entrance of all mines in which dangerous gas has been found to exist (General Rules, Mines Regulation Act, sec. 26), but unfortunately it does not recommend or enforce any standard of efficiency of the barometer; it does not require the instrument to be proved up to any standard of accuracy or delicacy; the consequence is that many colliery owners look at the matter from the economical point of view, and supply their pits with barometers purchased from local dealers in optical instruments, which, in comparison with a standard barometer, are found to vary perhaps $\frac{3}{5}$ of an inch at equal pressure.

On inquiring the price which the agent of one of the largest coal and iron proprietors of the midland district paid for his barometer, the answer was, 'We get them in the town, and pay about 18*s.* for them.' It is not possible that any accuracy can be expected in a barometer at the prices when about 8*s.* would be expended in mercury, 8*s.* in the wooden case and glass tube, leaving a balance of 2*s.* for labour, adjusting, etc. It will be observed that this estimate is made on the supposition that the thermometer is presented gratis.

As an example of the necessity of observing regularly the amount of atmospheric pressure in managing a coal mine successfully, in Haswell Colliery I was able to detect an increase of ·2 inch in the main return airway when the men left work, by means of a sensitive patent mining barometer, supplied with the safety indicator. This increase of the pressure of the atmosphere in the return, as indicated by the barometer, was probably due to the falling of the temperature of the air in the mine owing to the withdrawal of the men's lamps on their ceasing work, thus causing the air to assume a marked density. If, then, we can detect with a barometer so slight a variation from the normal atmospheric pressure, the instrument should not be left neglected and unobserved as it is at present in some mines. In a very able Paper read before the Royal Society, and published in their 'Transactions', 1872, page 292, under the following title, 'On the Connection between Explosions in Collieries and the Weather,' the authors, Messrs. Scott and Galloway, think that their evidence justifies the statement that meteorological changes are the proximate cause of a large majority of the accidents, and the evidence they have collected is so well sifted, that few persons could impugn the statement.

It is hardly to be supposed that science and engineering have reached such a height that we shall regulate the pressure of the atmosphere by the move-

ments of a lever. We cannot, therefore, remove the proximate cause, but we can compel the cause, viz., the variation in the pressure of the atmosphere, to act as a warning by means of the indication given by the barometer.

Let us suppose, for example, that a sudden and abnormal decrease in barometric pressure is observed to take place in the main return airway. An intelligent observer would naturally argue that the air required for ventilation was being drawn out of the return quicker than it was coming in by means of the intake; from this he would conclude that in all probability some obstruction, such as a fall of roof, had partially blocked up the airway on the intake side of the barometer station, or that a door had been accidentally shut that should have been left open, and that this was the cause of the abnormal decrease in the height of the mercury column in the barometer. He would recollect that if the return airway on the upcast, or 'return' side of the obstruction has cut through strata likely to give off gas, the airway would in all probability be filled with gas, and that a miner or wasteman travelling in a contrary direction to that of the air current would meet the full blast of the gas at a greater rate than ten feet per second. Now gas travelling with that velocity will pass the gauze of the lamp and become ignited. Having considered this, the mining engineer would take such precautions as should ensure safety

and a proper dilution of the gas. In all mining operations it is a *sine quâ non* that there should be either no ventilation at all, or else that there should be sufficient ventilation to dilute and render harmless the gases likely to be met with.

Hydrogen gas, whether lightly or heavily carburetted, does not explode when pure, but will do so if insufficiently diluted with air. The fire-damp met with in coal mines is a mixture of light carburetted hydrogen with common air. The fatal results of an explosion of fire-damp in the mine are not limited to the actual mechanical violence which it occasions to the sufferers, for when we examine the composition of marsh gas we see that this gas in exploding derives ten times its bulk of atmospheric air of the oxygen which it contains, or expressed by an equation,

$$CH_4 + 20_2 = CO_2 + 20\ H_2$$

The 4 volumes of oxygen contained by 20 volumes of air produce 2 volumes of carbonic anhydride and 4 volumes of steam, which become condensed, thus leaving 16 volumes of nitrogen remaining mixed with the carbonic anhydride. These two latter gases form the deadly after-damp which follow an explosion of fire-damp.

Taking another example, let us suppose that the temperature in some portion of the mine is higher than the average temperature of the whole mine, the engineer may then suspect that he has an indication

of 'gob-fire,' or 'breeding fire' as it is called in some districts. The gob-fire may either be the result of spontaneous combustion setting in the waste coal heaps, or the result of friction and grinding of the coal by the superincumbent strata. The effect is intense local heat, and frequently actual decomposition and ignition of the coal seam. Gob-fire is more frequent in seams of coal containing sulphur or iron pyrites. A sudden rise of temperature should, therefore, be carefully noticed, and the manager should take the precautions best suited to the case.

Thus we see that the barometer and thermometer in the hands of many mining engineers are mere dummies, placed in and at the mine only to satisfy the requirements of the Mines Regulation Act; but that in the hands of careful and thoughtful men who have for their sole object the successful management of the mine, they are instrumental in indicating what is taking place in the mine. There are very many colliery proprietors who appear to think that nothing is required but that the barometer should be kept clean and in its place. It is not enough to require the presence of a certain class of scientific instruments in a mine; what is wanted is some standing order which points out one person as responsible for observing the instrument, and for this latter requirement the Mines Regulation Act at present does not provide. On account of the various injuries they are liable to receive under-

ground, it is obvious that mining barometers should possess certain qualities which are not actually necessary in ordinary weather glasses.

We may enumerate these qualities as follows. The glass tube containing the mercury column should not be less than $\frac{1}{4}$ inch in diameter of bore, which should be turned accurately throughout. The thickness of the tube itself should be not less than $\frac{1}{8}$ inch, and the glass should be of the same quality throughout. The mercury column should be closed in from the 27th inch to the bottom of the tube; these precautions will ensure the safety of the instrument should a shot be fired near it. The scale for reading the instrument should be distinctly engraved, and we would leave out the words, *fair*, *rain*, *stormy*, etc., as they are no use underground, and are therefore not wanted. The barometer should *not* be placed in the lamp cabin below, but actually in the gate road going into the workings. A barometer and thermometer should be stationed at the entrance of the downcast current at the intake, and another pair of these instruments at the end of the main return airway near the furnaces; these two pair of instruments should be corrected for difference of level. It is advisable also that the thermometer be a separate instrument screwed to a metal plate.

It is by comparing the readings given by the barometer and thermometer at the foot of the down-

cast shaft with the readings given by those at the foot of the upcast shaft that we get an idea of the state of the atmosphere throughout the mine. In order to simplify the matter it will be found very useful if the barometer chart is engraved thus :—

Date	Baro. upcast	Baro. downcast	Difference less that due to difference of level
May 1, 4 P.M.	31·1	32·0	·9 *Made by* ______

This chart should be hung up at both barometer stations, so that the readings of both may be noted by any person coming into or going out of the workings.

It is surprising, now that the electric telegraph is so universally used as a means of communication and saving time, that colliery managers do not have a circuit laid from bank through all the deputies' cabins by running a wire, say from the engine-room at the surface down the downcast shaft through the cabins to the last. The terminal of this instrument in the last cabin should 'go to earth' by soldering the earth wire from the terminal to a rod driven into the coal; and here it will be necessary to caution those who are not practically engaged in laying telegraph wires, and are doing so from books on the subject, that unless the metals forming the 'earth' at the extremities of the line are of similar nature, a permanent current will be established on

the line, slightly deflecting all the needles. This is owing to the 'earths' being iron at one end and copper at the other, or iron and lead. They must be both iron, or both copper, or both lead, or a coal seam and water; the latter element will be found to make an excellent earth. By means of telegraphic communication, such as we have described, any sudden occurrence in-bye might instantly be telegraphed to bank, or if any man was required he could be summoned.

Very many and much-needed improvements have been made in machinery for mines, especially as regards the different methods of working and raising the coal, but still there is no reason for standing still. Many collieries use the old system of signalling, viz., the hammer and plate, although electric signals are now brought to such perfection, economy, and simplicity. The electric block bells are in use on almost every line of railway in the country, with the very best results. One of the difficulties in the introduction of electric bells in mines appears to be the question of the battery to work them. Daniell's sulphate of copper battery, though very constant, does not possess sufficient quantity for bell work, and requires careful cleaning and regular attention; but these objections are not applicable to the Leclanché battery. This latter form of battery is very extensively used on railways for working the block bells, and since it requires no cleaning or attention,

it cannot fail to recommend itself to colliery proprietors as especially suitable for the purpose.

The Kew Observatory grants certificates of the accuracy of all meteorological instruments; the law should therefore require all mining barometers to be certificated, and all managers to send their barometers to the mining inspector of the district, who should examine them periodically and compare them with the readings given by a standard-corrected barometer, which should be supplied as a *sine quâ non* to the inspector by the Government on his appointment to the post. There is no doubt that insufficient care is taken with respect to the use of these two instruments, and that more stringent rules are required to remedy this evil, which, although it may not actually cause accident, contributes nevertheless very largely to the safety of the mine and those employed in it.

In choosing barometer tubes we would advise our readers to get the glass tubes from some well-known instrument maker who can be depended upon, and leave the filling with him. By this means air bubbles and the many little things which cause failures will be avoided.

CHAPTER II.

DANGEROUS PRACTICES NOT FORBIDDEN BY THE MINES REGULATION ACT.

So far we have seen that without a good barometer and thermometer, properly constructed and observed, a mine is always more or less liable to explosion, obstruction of airways through falls of roof, gob-fire, and other accidents, without any other warning than we can obtain through the aid of science.

It is also evident that the class of the above-named instruments at present in use in mines in this country is not exactly what it should be; that to ensure their being accurate and sufficiently sensitive to meet the requirements of the mine further legislation should interfere and forbid the use of cheap, and therefore worthless barometers and thermometers, and that it should enforce the use of instruments of perfect accuracy. There cannot be a doubt that much might be gained by having electric communication throughout a mine, as proposed in the previous chapter.

We have now to consider the systems of signalling between the surface and the pit bottom at present in use in mines. The method of signalling with a hammer and plate is so obviously unsafe and now so antiquated, that we hope that few collieries have such an apparatus on their premises, although it still continues in occasional use in Durham.

Many systems are highly objectionable as far as regards their mechanical construction, especially some forms of electric block signals, and we would take this opportunity of cautioning those colliery proprietors who intend altering their signals that *perfect insulation* is absolutely necessary where electric signals are concerned, and on no account should an 'earth' be used; the circuit should be provided with a 'return' wire, thus rendering it what is technically known in telegraphy as a 'round circuit.' A short time ago (1876) I was asked to examine a system of electric-bell signals in a colliery from the bank to the pit bottom. On inspection I found the electrical connections were such, that on descending the shaft and pushing the line wire against the tubbing, the line wire made 'earth,' and thus caused the bell in the engine-room at bank to ring. Now one stroke of the bell corresponded to the order, 'Raise the cage.' Suppose a man to be on the point of entering or leaving the cage or the pit bottom, or that a tub were being put on, the engine driver would have raised the cage in accordance with his instructions, and in all probability an accident, perhaps involving loss of life, would have occurred.

On inquiry there would have been the usual amount of conflicting evidence, and the verdict at the inquest would be 'Accidental death,' and everything would be allowed to go on as before. The Board of Trade would not sanction on one of our railways an

arrangement of block signals, the electrical connections of which would allow 'Line clear' to be given if a line wire happened to come in contact. On the contrary, the Board of Trade have insisted on the block system as the safest and most effectual preventive against collisions. They sanction and approve of electric block signals when properly erected as a safe method of signalling the different trains on from section to section. The same electric bell arrangements should, therefore, be adopted in mines, and the system just mentioned should not be allowed to exist when the following clause is found in the Mines Regulation Act. General Rules, sec. 55. (*As to dangerous practices not expressly forbidden*) :—'If in any respect a mine is carried on in a manner which, though not expressly forbidden by the terms of the Act or by special rules, is nevertheless dangerous, the inspector may require the matter to be remedied, and the miner, agent, or manager is bound to comply with the requisition, or else submit to a reference to arbitration.' The reader is then referred in the Act to General Rules, sec. 46, where it states that 'the object of special rules is to prevent accidents,' and the next section under the same head says, 'Special rules have the same force as if they were in the Act.'

Many people would say that these were individual cases, one out of a thousand, and that because such practices exist, the mine inspectors are incom-

petent to effect the object for which they were appointed. We would, however, meet the first objection by asking those employed in coal mines how many times in the course of their shift they have seen dangerous practices carried on, although no doubt with complete immunity, and the latter by calling attention to the numerous and complicated matters that require the attention of the inspector elsewhere. It would be hardly fair to accuse the chairman of an extensive railway system of incompetency because a shunter, for instance, gets killed by his own carelessness in breaking the rules of the company.

We will say more. We know from personal knowledge that the mines inspectors of the midland and northern districts are able, practical men, not appointed in any undue haste, but after a careful consideration of the excellent and valuable experience that they most undoubtedly possess in all matters relating to mines. If these men cannot assist in reducing the casualties in mines, it is very evident that others cannot. It is a matter of common occurrence to find a tub standing on the top of an incline in a pit with the wheels unsecured, and which merely requires a push to send it off down the incline into the 'face.' The 'cager' at the bottom of the drawing shaft constantly walks across under the opening of the shaft at the pit bottom, although he is purposely provided in most collieries with a passage

round. If he fail to make use of this passage, he does so at the risk of his life. It must be stated, in fairness to colliery proprietors, that the majority of accidents in mines, we believe, occur through neglect or breach of rules, and that if the public were more aware of this we should not hear of the accidents so often thoughtlessly attributed to mismanagement on the part of the owners. Until miners can be made aware that carelessness in mines may amount to criminal negligence, many forms of accident will continue to occur annually.

Many accidents might be avoided by putting up boards at the entrance to headings, when blasting operations are being carried out, cautioning persons that shots are being fired there. I can speak from my own personal experience on this point; for once on entering a heading I heard a noise like a blower of gas escaping, and on walking up to the spot from which the sound appeared to come I found a fuze burning in an unexploded shot-hole, which I was unable to extinguish until I had cut it in half. Had I not heard the fuze burning the shot would have fired in my face. It may be not inopportune to mention here that many fuzes, though apparently blown out, are not really so, but will go on burning in the case, especially those known as submarine fuzes. A fuze, well-known for its certainty of action in wet localities, and therefore much used for blasting purposes in mines, called 'Bickford's Patent Fuze,' is

especially liable to this; so that in all cases where it is desirable to extinguish a lighted fuze it is always best to cut it off as near the tamping as possible. This effectually extinguishes it.

Many of the accidents which occur through premature explosions in blasting operations are due to the hurry in which they are carried out. We know that the owner looks to the quantity of coal raised, that the manager looks to the cost of raising with an eye to its reduction, and the men, if at piece-work, to the amount they can earn in a given time. Now, under these circumstances, it is extremely probable that the time allowed for the operation will be insufficient to enable those entrusted with the duty of carrying it out to make the necessary arrangements to ensure safety. Persons who are constantly exposing themselves to danger are apt to become so familiar with it as finally to ignore it altogether, and miners grow careless by a breach of rules laid down by the Act, which is not punished at once, and severely. Miners require closer supervision.

The real cause of half the accidents in this country is that a given practice is not recognised as dangerous until the accident takes place. Riding in tubs, for instance, is found to be dangerous; but there are many boys who persist in doing so till they meet with some accident that probably leaves them crippled for life. If they were warned individually, they might pay some attention to the

caution; but since the Act can only give a general warning they conclude that it applies to everyone but themselves. The practice of riding in the tubs in mines is much too common, and should be forbidden, as it is a principal source of injury.

CHAPTER III.

THE RELATIVE STRENGTH AND MERITS OF THE EXPLOSIVES USED IN MINES.

The ignition of gas after the explosion of the charge in the bore-hole is a very great source of accident in blasting operations. And here we would call the attention of colliery owners to their brattice-cloth. A kind of brattice-cloth is now sold that is highly inflammable, and another kind that is partially so. Those who advertise and guarantee these two forms of brattice-cloth as being uninflammable should be severely punished. Of all precautions, the one of uninflammable brattice-cloth is the most essential. If an explosion takes place it communicates from one drift to another, firing the brattice-cloth, and frequently firing the coal seam. Scott (Manchester) has patented an uninflammable brattice-cloth that we can personally guarantee as being safe, having tried many experiments with it, but we believe his patent has

expired and become the prey of a peculiar class of inventor at present, thanks to the present Patent Law, very much in force –viz., those persons who pirate patents by advertising an inferior article under the name of some really good invention at a lower price.

It is quite impossible to determine with certainty whether gas exists in any quantity behind the mass of coal to be dislodged, but occasionally we get external indications (frequently whilst drilling the shot-hole) that in 'shooting down' the coal, as it is technically called, a considerable quantity of gas will probably be given off.

It is usual to inspect the place and try it for gas with a Davy lamp before the fuze for exploding the shot is lighted; yet in spite of this precaution explosions occur which, on subsequent inquiry, seem to point to the ignition of no inconsiderable quantity of gas by the explosion of the shot.

The terrible explosion at Swaithe Main Colliery, in December 1875, by which 109 men were killed, may have been due to this cause. At the inquiry into the unfortunate occurrence, considerable attention was given to the supposed ignition of the coal-dust, and the spread of the explosion by this means; but the primary cause of the explosion seems to have been the manner in which some blasting operations were being carried out.

The question of the restriction of the use of explo-

sives in mines came under the notice of the Government in 1876, but the report presented by the inspectors stated that they were unable to agree.

It is absolutely necessary that explosives of some kind must be used in coal mines. We have therefore to find the *explosive that can be used and stored with the least danger, and yet that shall produce the greatest effect?*

The first thing to observe is that rapid combustion is required. Now, explosives that are granular in their composition are not, as a rule, very rapid. Those that are cellular are so. We notice this especially with the action of sawdust powder as compared with gun-cotton.

At present the explosive agents used in mines are gunpowder, gun-cotton, cotton-powder, tonite, and all the compounds of nitroglycerine and infusorial earth, such as dynamite, lithofracteur, etc.

The practical objections to gunpowder are:—

(1) The quantity of dense smoke evolved after explosion compared with that evolved by nitro-compounds of equal or greater force.

(2) The danger incurred in moving it from place to place, owing to sparks.

(3) Its explosion or ignition from a spark when tamping with improper tools.

(4) The difficulty of using it when fissures occur in the rock.

These are the principal objections to the use of gunpowder in mines, whilst its merits consist in the

fact that it is a stable compound, of which the properties are well known, it is also asserted that it does not shatter the coal, like other explosives.

The objections to gun-cotton are twofold. In the first place, grave complaints are made of the nitrous fumes after ignition. We would meet this by stating that if the hole is not overcharged with gun-cotton, and if a wooden plug is placed in the mouth but *not* rammed home, this objection will not exist.

The other objection is that it shatters the coal. In the hands of persons who understand its behaviour this should not occur.

The objections to the use of dynamite are more worthy of careful consideration. It is uncertain in its behaviour in extremes of temperature, and the men complain of the effect upon their health in close headings. These are real objections, and in our opinion dynamite, and all the existing forms of nitroglycerine, are improper explosives to be placed in the hands of men who persist in drilling out missed shots and breaking rules made for their own safety. Of course the manufacturers of it say it is a perfectly safe agent; and there is a story told of a celebrated chemist, that when his son was blown up, trying experiments with nitroglycerine, he remarked next morning that it was a perfectly safe chemical compound. Agents for the sale of a particular substance are naturally unwilling to state the objections to its use. Lithofracteur and the remain-

ing compounds of nitroglycerine are all equally objectionable on the above grounds.

We have next to consider an explosive lately introduced by Messrs. Curtis & Harvey for blasting purposes.

It is known as the E.S.M. powder, and is an improved form of ordinary gunpowder. The objection to gunpowder—viz., its slow combustion—is here overcome by the discovery of detonation and its effect on granular explosives.

Detonation is the simultaneous conversion of all the grains of the powder into gas, and is thereby distinguished from *simple explosion*, in which the conversion takes place gradually from one grain to another.

If the whole volume of the gas be evolved instantaneously, it is obvious that the whole force of the explosion will be thrown upon the sides of the shot-hole.

Gunpowder, when detonated, exerts four times as much strength as when it is ignited by simple explosion, and the failure of the introduction of this system of exploding powder arose from the difficulty in producing a good detonator.

The advantages claimed for the E.S.M. powder are:—

(1) That its strength is equal to No. 1 dynamite when detonated.

(2) That it is cheaper than dynamite.

(3) That it requires a light tamping.

(4) That it gives off much less smoke than ordinary powder.

(5) That it is not liable to explode by exposure to the direct action of the sun's rays, percussion, or self-ignition.

The cost per 100 lbs. is 5*l.*, and the cost of the detonators, primed and fitted with insulated wires for firing by electricity, is 3*s.* 6*d.* per dozen.

Thus we see that a saving of 6*d.* per lb. is effected over gun-cotton.

So far, then, it would appear that gun-cotton and E.S.M. powder are the two explosives best suited to our purpose.

The following table will show the reader the relative strength of the explosive compounds at present under our consideration for use in coal mines:—

Compound	Simple Explosion	Detonation	Relative weight of gases	Heat disengaged by 1 lb.	
				Simple Explosion	Detonation
Gunpowder . .	1·00	4·34	·014	1316 units	1318 units
Nitroglycerine	4·80	10·13	0·800	3097 "	3200 "
Gun-cotton . .	3·00	6·46	0·850	1902 "	1909 "

It appears from the foregoing table that dynamite containing 75 per cent. of nitroglycerine possesses a relative strength of 3·60 in explosion and of 7·60 in detonation. This is founded on the assumption that the nitroglycerine in mechanical combination with the absorbent material is capable of exerting the same force as when in a pure state. Thus, for instance, gunpowder, if fired by detonation,

is much stronger than dynamite when the latter is simply exploded, and the latter when detonated is superior to the former only in the ratio 1·75.

I will now briefly enumerate the properties of the two explosives best suited for blasting in coal mines—viz., gun-cotton and E.S.M. powder—fired by detonators.

Gun-cotton is insoluble in water, and is but little affected by heat until a temperature of 300° Fahr. is reached, when it decomposes and burns away silently with a bright yellow flame; but if the cotton is in a confined space it will explode. This latter property is not sufficiently recognised in drying gun-cotton in ovens. No shock will detonate it. If fired in a confined space it explodes without producing any visible flame or smoke, and the more confined the space the more violent will be the explosion; the latter property is, of course, possessed by all explosives that evolve a large quantity of gases suddenly. If fired in the open air with a detonating cap, gun-cotton explodes with great violence, but no visible flame is produced.

If a rock to be blasted has been drilled and is found full of fissures, powder cannot be used except as a cartridge, and when exploded the gases make their escape through the fissures instead of exerting their force on the sides of the bore-hole. This is a case, then, for which gun-cotton is adapted. We have seen it used in close headings with great effect,

and heard no complaint of nitrous or irritating fumes after detonation.

A deputy of Shire-Moor New-Winning Colliery informed us that, in his opinion, gun-cotton was an excellent explosive for mining operations, and that he used it in preference to dynamite or gunpowder.

It would be more satisfactory to adopt this explosive in place of powder, and fire it with an electric fuze and firing battery, the management of which might remain in the hands of a special staff of men, who should act with the authority and under the directions of the fire-trier or some recognised sub-officer. Professor Abel, the chemist to the War Department, and Mr. George André, a mining engineer of no small reputation, have experimented on gun-cotton and fuzes for some time, and report it to be a tractable agent. We have ourselves tried a series of experiments with it, and find it perfectly safe if properly treated; but we have noticed the following objection when using it in close headings: it is not possible to calculate with any degree of certainty the resistance that the rock exposes to the expansion of the gases, and therefore there is a risk of overcharging the shot-hole, when nitrous fumes are evolved on firing, owing to incomplete combustion.

The recklessness of miners in using all kinds of explosives is an abundant source of accident. We read in Gladstone's 'Life of Faraday' that when Professor Faraday was appointed by the Government to enquire

into the circumstances which brought about the disastrous accident at Haswell Colliery, in Durham, he was offered on descending the pit the most comfortable seat the mine could provide, which, on examination turned out to be a bag of gunpowder!

Men are repeatedly cautioned against drilling out shots, yet they will persist in so doing, as long as they have to find their own powder. There is nothing so dangerous as this practice of drilling out missed shots. The law says 'a shot that has missed shall not be unrammed,' but the miner considers that the 3 lbs. of powder is worth risking his life for. He may drill out the shot ninety-nine times out of a hundred, but the hundredth time he loses his life or eyesight by his folly. We would advise the printing of rules to be observed for the use of powder on the powder-cans as well as on the board of rules.

Only trustworthy and intelligent men should be employed in blasting operations, and certainty of action of the fuze and an entire control over the whole arrangement may be secured by the use of an electric detonating fuze and firing battery. Under these circumstances, gun-cotton forms a safe explosive, good for storing and economical in use, and the use of which ensures a large amount of immunity from accident, to which those are liable who use gunpowder and dynamite. A limited quantity should be served out from the colliery magazine to *one* man, who should receive his canister at the

magazine and proceed directly down the pit *alone*, and take his canister without any delay direct to the spot where he is required.

If possible the shots should be fired when the men are out of the pit, changing shifts, which in all cases should be done at bank; but above all no shots should be fired, when naked lights are used, without first extinguishing the light, and carefully testing the place with a lamp before re-lighting the candles; and, we should like to forbid the use of naked lights in any mine where shots are being fired. A number of lives are yearly sacrificed by accident whilst blasting, and whilst naked lights are allowed, and gunpowder used, the sacrifice must continue.

Since writing the foregoing the new patent cotton powder has been brought out, and the following is an extract from one of the leading mining papers on it:—

New explosives are being invented almost every day, and dozens of old ones are in open competition for the favours of the miner. In consequence there is great danger that the users of explosives will be continually trying new compounds, and losing much valuable time, to give apparently fair play to some of them which are not suited to their purpose, while a little consideration on the nature of the proposed explosive might, *à priori*, settle almost the question immediately.

The qualities required of an explosive are, as a matter of course—

1st.—Strength.	3rd.—Absence of noxious gases.
2nd.—Safety.	4th.—Cheapness.

Let us examine the divers compounds known under these

four views, and if an explosive can be ascertained to possess at once these four characteristics in the highest degree, it ought to be pronounced 'the explosive of the future,' and will thereby deserve the earnest attention of the consumer.

Strength comes almost first in the estimation of all miners, and with some good reasons, and in practice strength is found to appertain exactly to the explosive which theory points out as the strongest. Theory shows that three qualities are required to make an explosive strong, viz. :—

1st.—A given weight of it must give a large amount of heat on explosion.

2nd.—It must occupy the smallest possible space.

3rd.—The explosion must communicate through the mass of the charge in the shortest possible time.

The quantity of heat given out by the unit weight of the explosive is really the force which, if applied in the smallest space and in the smallest time, will give the maximum disrupting or projecting effect.

All physicists know how to arrive by computation at the amount of heat a given explosive will disengage on explosion, and the *modus operandi* of such computation, together with examples, are well explained in a memoir, by M. Berthelot, on 'Explosive Substances.' In M. Berthelot's concluding table on the amount of heat given out by the explosion of divers substances we find the following figures, which may be taken as types of their classes :—

1st.—Gunpowder average . . .	600 units.
2nd.—Gunpowder, chlorated . .	1,000
3rd.—Nitroglycerine, pure . . .	1,320
4th.—Gun-cotton	590
5th.—Gun-cotton, chlorated . .	1,420

The class gunpowder may be taken to cover all those explosives which are simple mixtures—more or less incorporated—or do not contain a sufficient quantity of a nitro-compound to be detonated.

Gunpowder chlorated is gunpowder in which the nitre is replaced by chlorate of potassium. It is too dangerous to make and use.

Pure nitroglycerine gives out a large amount of heat, but is also a most dangerous substance. All the explosives containing this substance—such as dynamite, lithofracteur, etc. —will give an amount of heat proportionate to the quantity of nitroglycerine in the composition. For instance, dynamite as usually understood, and containing 65 per cent. of nitroglycerine, will give 980 units. Lithofracteur gives more heat, according to its composition; but the ingredients of gunpowder which enter into its composition, and especially sulphur, are most unsuited to form a chemically stable substance.

Gun-cotton, with its 590 units, makes rather a poor appearance, and keeps itself in the market on the score of its safety, and the high rate of its explosion gives it a great advantage over gunpowder in short holes. The substance known as Patent Gunpowder belongs to this class of explosives.

Gun-cotton becomes very much stronger if mixed with an oxidising substance, the best effect being obtained by using about equal weight of gun-cotton and chlorate of potassium, but anything that contains a chlorate must be put down as especially dangerous. The next best mixture is gun-cotton with nitrate of baryta—that is 'cotton powder'—which gives about 995 units of heat, or a little over dynamite. This nitrate of baryta offers some very interesting peculiarities, which make it thoroughly suited to its application. It contains the greatest amount of oxygen under the same volume; it is very ready under the detonator; but being very dense it is but slow in ordinary combustion, so that a cylinder of dry cotton powder burns by inflammation like a common pitch torch.

Another advantage of the composition of the cotton powder, or 'tonite,' as it is called on the Continent, is that

the nitrate of baryta, resolving itself upon explosion into carbonate of baryta, or heavy earth, it takes down in a few seconds all the smoke, vapour, and carbonic acid gas that are generated by all explosives. Cotton powder on this account, and giving the greatest amount of heat of all safe explosives, is, therefore, on that score the 'explosive of the future.' But let us not anticipate, and proceed to the other views as enumerated above.

The next point affecting the strength of an explosive is its compactness; this point is settled by the density of the charge, thus—

Gunpowder	1 or a trifle over.
Dynamite	1·50
Cotton powder	1·50 to 2·00
Gun-cotton and patent gunpowder	1 or under.

The explosive of the highest density, occupying the smallest space, gives on that score the greatest pressure, all other circumstances being alike. Dynamite, being pasty in its ordinary condition, fills a bore-hole somewhat better, but this is counterbalanced by the danger of smearing the hole sides when rammed down, which causes a certain amount of the unexploded substance to be blown out with the tamping, and is afterwards breathed by the miner, while cotton powder is easily made to fit by using moist clay or water, so as to fill any vacuity.

We come now to the third point affecting strength—that is, the rate of explosion. This is of great importance, for this characteristic gives an explanation to a great discrepancy in the theoretical computations as expounded by every inventor, who bases his reckoning merely on heat and space; and the proof of this is apparent when we consider that the heat given out by the worst nitrate mixture is only one-half below that of nitroglycerine, while its mining effects are very often but one-tenth of the effects of the latter.

All nitrate mixtures of the gunpowder type inflame and

explode through a spark or flame penetrating gradually between the grains, and burning from the surface of the grains inwards. This explains the low pressure given under a tamping, or projectile, small enough to be removed easily at a comparatively slow speed. The rate of burning can be measured by a chronograph when the charge is burnt in a cannon, and is a very appreciable part of a second. All nitro-compounds —such as nitroglycerine, gun-cotton, and cotton powder— explode through the mass, and the transmission of the detonating effect can be compared to the atmospheric waves when transmitting sound. This explains why nitro-compounds can be used without apparent tamping, their own mass and that of the adjoining atmosphere being sufficient to produce the retroactive effect. All nitro-compounds are on the same footing in that respect.

In conclusion of the examination of the cause tending to give an explosive the greatest strength it is opportune to mention that cotton powder gives the greatest amount of heat; it is the densest, and is equal to the others of the nitro-compound class in its rate of explosion. Some physicists introduce in their comparative computation the quantity of gas given on explosion, but this is found to be unnecessary, as heat alone is force, irrespective of the quantity of the medium used, although the quality of this medium interferes with the initial pressure. But the quality of the gases does not vary much amongst the divers explosives claiming the attention of the miner.

An eminent man who has done much towards endowing industry with a powerful explosive, and whose researches have greatly aided in throwing light in the way this article attempts to follow, is Mr. Alfred Nobel. This gentleman has experimented with almost all the explosives known, and in a lecture before the Society of Arts he gives publicity to his researches. It is very interesting to see how the results obtained by Mr. A. Nobel tally with the above findings. Let us take Mr. Nobel's figures in a simple form, taking nitro-

glycerine as the strongest explosive practically known, and put at the comparative figure 300; then the others follow suit with their respective marks, thus:—Lithofracteur, 150; dynamite, No. 1, 217; Abel's gun-cotton, compressed to a density of 1,215; and in the same page of the report of the proceedings he goes on to show that gun-cotton of density 1 is less than half the strength of nitroglycerine, bulk for bulk, on account of the superior density of the latter. For the same reason cotton powder, when used as in slate quarries, with a density of about ·900, comes off with a figure of 186; with a density of 1·50 to 2 that figure would exceed that of dynamite. Mr. A. Nobel's figures are, however, under a disadvantage—that is, of not being obtained by practical means. They were obtained by firing a very small charge in the centre of the bore of a large mortar, so that those explosives which require tamping were under a disadvantage; but with the exception that they show dynamite to be much superior to lithofracteur, which is evidently an error, we can take his table as a check upon the foregoing.

So, from the above, the deductions are that the order of merit for each explosive is (beginning with the strongest):—

1st.—Cotton powder, density about 1·50.
2nd.—Lithofracteur.
3rd.—Dynamite, with 75 per cent. of nitroglycerine.
4th.—Gun-cotton (Abel's) } Density 1·00.
5th.—Patent gunpowder }

Curtis & Harvey's extra strong blasting powder exploded with detonator or strong firing cap, giving about one-half the effect of No. 5.

We now come to the second quality required by an explosive to command the attention of the miner after strength—that is, safety. In discussing this point it will be advantageous, for the sake of shortness, to couple it with the third requirement—that is, absence of noxious gases or fumes.

The chemical stability of the compound, the facility with

which it can be made pure, and the resulting products of the explosion, will be materials required before the question can be settled.

The chemical stability of gunpowder is admitted by all, if it is well made and the sulphur free from sulphurous acid. The temperature at which it will explode is also very satisfactory, but its hardness renders it liable to fire by friction, and it is also easily fired by a spark; and, when so fired in large quantities or in a bore-hole, may cause serious accident.

Amongst the nitro-compounds two principal classes exist —the class based upon nitroglycerine, and that based upon gun-cotton. Their stability depends upon the affinity with which they are compounded; and as the kind of reaction which takes place on the glycerine or cotton being turned respectively into nitroglycerine and gun-cotton is similar, this affinity can easily be compared. This has been done by M. Berthelot, who found that the stability of the gun-cotton compound is theoretically four times that of the nitroglycerine class; and this is borne out by experience, as it is well known that the gun-cotton compounds, such as cotton powder, require a much stronger detonator to fire them than those required by dynamite—that is, the cotton powder can stand a greater blow or more friction than dynamite. The cotton powder is also safer than its congeners, gun-cotton or patent gunpowder, as it is mixed with a peculiar nitrate, very dense and very slow to burn. The charges of cotton powder being also entirely covered with a waterproofing coat, they are free from ignition by sparks.

Common gunpowder gives out on explosion a large volume of smoke, not particularly injurious, but very annoying in underground mines. Dynamite gives out steam, nitrogen, carbonic acid gas, and nitrous oxide; and often a large portion of the charge having been smeared against the sides of the holes, and escaping explosion, is blown about in fine dust and breathed by the miner; hence the serious effect the use of

this explosive has on the health of the miner. Lithofracteur is in the same category, with the additional danger mentioned above, and caused by the sulphur. Gun-cotton and patent gunpowder give on explosion steam, nitrogen, carbonic acid gas, and carbonic oxide. This latter is the dangerous element, as it is evolved in large quantities, and is of itself, when mixed with the air, an explosive, and has caused serious accidents, whilst it is very noxious.

Cotton powder leaves nothing but steam, nitrogen, and a residue of carbonate of baryta or heavy earth, which falls to the ground immediately, leaving the atmosphere as it found it.

The perfection of this compound is guaranteed by the resources of modern science, and the facility with which each of its ingredients can be purified. Suffice it to say that cotton powder being made up of a very finely crushed gun-cotton, is very easy to wash, and the process of purifying, as carried on at Faversham, is so ample, that the gun-cotton is generally pure after two hours' washing, but is allowed to wash for many days, for the sake of extra safety, as it costs but very little more to do so.

Cheapness means evidently the comparative cost for work done, and the certainty and handiness with which a hole can be charged. It is evident that the strongest explosive ready in solid charges, perfectly waterproof, and sold at the same price as the well-known accepted articles, is the cheapest, because more work in a given time is done with it.

We have tried a considerable number of experiments with this explosive, and find that it is all that it claims to be. This form of gun-cotton has been admitted under the 'Clearing House Rules' by the railway authorities, and is transported by rail on the same terms as ordinary gunpowder. We strongly advise a fair trial being made of it in mines, as the obnoxious

fumes complained of in many cases where gun-cotton is employed appear to be entirely prevented by its use.

CHAPTER IV.

MECHANICAL ACCIDENTS THAT MIGHT BE PREVENTED.

We next come to a source of accident, more commonly causing injury than actual death, which can and ought to be stopped, viz., accidents from runaway tubs, etc.; that is to say, injuries received through tubs being unscotched on inclined planes; want of manholes, or manholes being made a place for depositing rubbish; tubs running back into the 'face,' etc. Now, all these accidents, which are quite inexcusable, occur frequently, and are more generally due to the carelessness of the miners themselves than to any negligence on the part of the manager.

In some mines where inclined hauling planes are much used, the tubs are fitted with a drag, which, however, frequently gets broken off or fails to act when required. In all matters relating to checking the speed of a moving body it is absolutely necessary that the friction should be applied instantly before the acquired momentum is set up; in the event of tubs 'running back' the break should apply itself instantly, otherwise it is of no use. If one set

of wheels on each tub were provided with an excentric block on the axle and a catch, they could only run one way, unless the catch was up. The question of manholes rests entirely with the manager of the pit: if he is careful he has them; if not, he does not trouble himself about them.

Manholes should be conveniently situated, and whitewashed, in order to make them conspicuous; they should accommodate two men at least, and should be cut on both sides of the wagon-way, and be kept clear of rubbish. The first manhole should be about twenty yards on the *right* hand side of the road; the next, twenty yards on the *left* hand side, and so on. It is not an uncommon thing to find manholes filled with pit-props, etc. The miners themselves should bear in mind that they are places of refuge, and should be kept as such. They should not be used as a magazine, as appeared from the evidence after the explosion of dynamite in a tunnel being driven for the Great Western Railway by the Diamond Rock Boring Company, in March 1876.

A rail left out, the sinking of the roadway, or a pit-prop left in the way are frequent sources of accident, and miners cannot be too earnestly cautioned and continually reminded that they are bound to consider the lives of their fellow-men before saving time and money.

From a theoretical point of view falls of roof

should not occur, but practically it will be found quite impossible to prevent such an occurrence happening at some period or another. Propping roofs is an expensive operation, and accidents frequently occur whilst the men are putting in the timbering. The reader would feel very uncomfortable if he were told, 'The roof is unsound and likely to fall; you had better take some timbering and go and prop it up.' Yet this has to be done every day by men told off for the duty.

An oak prop of 1 ft. 6 in. in diameter would be bent double by the grinding of the roof if a slip were to take place. There certainly is in some collieries a desire to work too close, with a view of lessening expenditure in such matters as pit-props; the supply is insufficient; and being largely imported from Norway, they naturally command a good price in the market. Falls of roof are more common in the return airways, from the neglect of the master wasteman, who is supposed to examine the returns periodically. 'Travelling the waste,' as it is technically called, is not an agreeable occupation, and should be well paid. The practice of trying the roof with a pick for flaws is a very dangerous one, and many lives are endangered every day through doing this.

Falling into sumps (holes to drain the mine free from water) is much too common. The Act requires them to be securely fenced, but they are generally covered with a lid, the timbers of which are sometimes rotten.

'Falling away' down the shaft is not now a common occurrence, since the mouth of it is generally well fenced, and the presence of the banksman is a great safeguard. Injuries received through things falling down the shaft can be prevented by enforcing the presence of the banksman or some other person whilst men are engaged at work in the shaft. I once saw a hammer, which was tossed to a workman at bank, slip through the fencing and go down the shaft, in which some sinkers were at work; it luckily missed them all; but it shows that the fencing should be tolerably close.

Strangers should never be allowed to loiter about near the mine, as they may very possibly throw a small pebble down, entirely forgetting the acceleration of the falling body. Icicles on the framework should not be allowed to accumulate, as they attain a great size in a few nights of frost after a warm sun in the middle of the day. Cases have occurred where bricks have been wilfully and maliciously thrown down shafts to injure those at work. The whole of their system of preventing men working is neither more nor less than an interference with the liberty of the subject, and it is inconceivable that such a thing should be tolerated by the workmen themselves. In some of the mining districts picketing is regularly carried on, by which a man is afraid to go to work if the pit is on strike, when perhaps his family are starving. If a working man were to add

up all he pays to his union, and the amount of wages he loses by strikes, he would find that the mere interest due annually upon that sum would very nearly equal the payment received by him as a member of the Union.

The prohibition of single shafts in mines has prevented many accidents, but it was not done until the Hartley Colliery accident took place, when all in the pit, both men and horses, lost their lives by the breaking of a pumping spear, and consequent choking up of the shaft with *débris*. Even now the mention of that accident is disliked by the miners of that district. A miner ought to be, and generally is, a brave man. His fault is that he too often spends his high wages in luxurious living. Few care to save any part of their wages, which is merely a traditional custom and not a necessity.

If a company were established on a good sound basis, and managed by men whom the miners have confidence in, for the purpose of building houses, etc., very many miners would be glad of this method of employing their surplus wages. For instance, let us suppose that they pay in 4*s*. a week, which would be an annual payment of 10*l*. 8*s*., and receive at the end of five years a cottage of the value of 100*l*., a piece of land, or shares in a colliery, and continue to pay this sum for the period of ten years, they would at the end of that term find themselves owners of their own cottage, and would

have had the use of it for five years as well. There are building societies who work on this principle, but miners will not put money into ventures unless they know and have confidence in their managers.

CHAPTER V.

OVER-WINDING.

This form of accident can only occur either through failure of machinery and winding-gear or neglect on the part of the engine-driver; but, by whatever means it may be brought about, it can be prevented. Indicators, as required by law, to show the position of the cages in the shaft, and powerful breaks, have not prevented it occurring; but if collieries would only adopt the detaching-hook much might be done. There are very many patterns of this form of hook differing but little in construction. The principle is this, that when the cage is wound up above a certain point the winding-rope is automatically detached from the cage, and the cage is kept up by an arrangement in the framework, on which the pulley-wheels are hung. It is hard to say which is the best form, for they are all good. Perhaps the owner may feel that if the engine-driver were aware that nothing could happen from over-winding

he might get careless; but it is a fact that with a self-detaching hook to a winding-rope there cannot be a case of over-winding, and that alone should be sufficient to warrant its general introduction into mines. The outlay is but little compared to the expense incurred by over-winding, and a great deal of unnecessary anxiety and responsibility is taken off the shoulders of the engine-driver.

A steam-break, now in use in some of the Earl of Dudley's collieries, is one of the most perfect mechanical arrangements of its kind, and can be put on and taken off with great nicety. The principle is much the same as that of the steam hammer, the break and block being the hammer. Steam is admitted and the break put on by depressing a lever in the floor of the engine-room with the foot. This in itself is one of its merits, for the engine-driver can have his hand on the regulator and his foot on the break without stirring out of his chair. I saw the inventor of this break lower the cage down the pit with full steam turned on, but regulating the velocity of its descent and the speed of the engine with the break, finally bringing it to a standstill with the steam full on. A break of this kind is a most valuable addition to the winding machinery of a mine, and deserves the highest approbation.

Another source of accident is the breaking of the winding-rope or guide-ropes. The breaking of a winding-rope is like the bursting of a gun from a

flaw in the metal—no one knows the danger till the accident occurs. A rope may be run for six months without giving any sign of weakness, and then may suddenly snap, precipitating the cage and its occupants to the bottom of the shaft. Few collieries can be accused of working a rope when it is known to be unsafe with a view to economy; yet winding-ropes, like the tires of wheels, will contain flaws, however carefully they may be manufactured or subsequently used. The only remedy for this class of accident is, therefore, to have an automatic break attached to the cage, which shall grip the guide rope in wooden guides when the rope gets too slack. This precaution would be found to act well.

The rapid-winding collieries of the present day seldom have their winding engines more than one hundred yards from the framework and pulley wheels, but at Dudley and Wolverhampton they are as much as four hundred yards from the framework in some of the old mines of that district. It is much better to have the winding engine close to the pit's mouth, when the engine-driver can see what he is doing, and the length of the rope is less exposed to changes of temperature.

The breakage of a guide-rope may cause the descending cage to come in contact with the ascending one, and is generally due to the ropes being slack and not quite vertical in the shaft and parallel to each other. The colliery engineer should see to

this, keep them braced up, and gauge them occasionally.

Mechanical failures and flaws in wire ropes—which are as a rule prepared and tested with extreme care—are not of very common occurrence. Wire guide-ropes are far preferable to wooden guides. They are more easily greased, stronger, and in the end cheaper, requiring but rarely to be renewed. If a wire guide wears out too quickly it is a sign that the guide-ropes are too near together. If one part wears brighter than another the ropes want bracing up and gauging with a plumb-line. A washer of elm in the rings of the cage through which the guide-ropes run will be found very effective, and less wear and tear will be the result. It should be kept well greased, to prevent its taking fire from the friction whilst the cage is running. Two wire guides are quite sufficient, if kept well braced up. Drawing water in a skip strains them very much if the skip is not full. In the Appendix will be found a description of an improved break which is automatic, and supersedes the detaching-hook entirely.

CHAPTER VI.

FIRE-DAMP AND BLOWERS OF GAS.

We next come to a cause of accident that for years has puzzled mining engineers to avoid, viz., the presence of insufficient diluted carburetted hydrogen in the airway of a mine. To speak of the causes which bring about the ignition of the gas in a coal mine would be but to enter into a dismal summary of all the inquests and inquiries held upon explosions. What we can do with advantage is to inquire into the possibility of preventing such explosions—first, by preventing as far as practicable the existence of the gas; and, secondly, by preventing the gas finding a spark in a naked light in the mine; and in speaking of this question colliery proprietors as a body cannot be acquitted of negligence or oversight.

The commonest cause of explosions is without doubt the firing of a shot. A glance at the Report of the Mines Inspectors will suffice to show that gunpowder is, directly or indirectly, the cause of a large percentage of the loss of life in mines. A spark or the flash of the powder may ignite a little gas, which in its turn ignites the coal-dust, and so communicates perhaps with a large quantity of gas elsewhere.

If the precaution mentioned in the chapter devoted to the use of explosives in mines were carried

into effect I will venture to say that the explosions would be very much less frequent about the Wigan district. Is it common sense to have fuzes burning when locked lamps are used? They now use a Silvertown safety fuze and firing battery, as is in use for firing submarine charges. Is it safe to fire a shot and then examine the effect on the coal with a naked light? Yet such things are done, and done regularly as a matter of course. Whoever is employed in blasting coal in a mine should have a locked lamp. A very large quantity of gas is sometimes dislodged by a shot, and must ignite at the naked lights of the men at work. Some men do not even take the precaution of standing to windward of the shot whilst waiting for it to explode, and so escape both the smoke from the gunpowder and the gas, if any is given off after the shot.

The next source of explosion is due to insufficient or bad ventilation. A miner's advice to a young mining engineer was: 'Never bottle up gas in a mine and then think that it does not exist because you cannot find it with the lamp.' And very good advice it was. It is very important that the return airways of a mine should not become filled up or choaked with *débris* from the roof, for gas is liable to accumulate behind the obstruction on both sides, and may cause explosion. Gas frequently accumulates in recesses in the roof which are not swept by the air-current. It may easily be dislodged by placing

a piece of sheet-iron at such an angle as shall cause part of the air-current to be diverted and pass up into and out of the recess. It is a difficult question to answer satisfactorily whether gas is continually forming in the coal seam or whether there is a certain limited amount. There is no doubt that any system of ventilation such as will contribute towards keeping the gas in the coal-seam by external pressure is a mistake, and contributes largely to spontaneous combustion in some coal-seams; it is safer to allow it to exude than to dilute it well with air and carry it off. The ventilation in mines is considerably better than it used to be; in fact, a great deal of attention is being paid at present to the matter.

The Guibal ventilating fan has given excellent results. In this invention the air is carried down the pit by means of the revolutions of the fan driven by steam-power, and the great advantage it possesses over other forms is the ease with which the amount of air circulating in the mine is regulated. Deficient or insufficient ventilation is not so frequent as badly-disposed ventilating arrangements, which interfere with the proper cleansing of the pit, such as badly fitting air-doors, air-doors left open that should be shut, or *vice versâ*. The remedy for the latter is to have them weighted like a swing door. Sometimes miners, perhaps from their fear of being taken off a bit of piece-work, will not report gas which may exude after the fireman has made his

rounds and certified the locality to be clear. They are perhaps working with a naked light, and cannot at once discern whether the gas is undiluted or not. A lamp should be supplied to every gang working with naked lights, and one man held responsible for its proper use, etc. As an instance of the recklessness of miners as a class and of the little effect an accident in a district has of checking it I quote the following from one of the daily papers :—

'Two miners were had up before the magistrates and fined for having held a naked light to a blower of gas coming out of the seam ; and this took place in a mine in the same district and within ten days after the Swaithe Main Colliery explosion, in December 1875, when 105 lives were lost.'

We can never expect a decrease in the annual amount of lives lost by accidents in mines until it is brought home to the miners that there are others besides themselves in the mine, and that when they carry on a dangerous practice they are risking the lives of their fellow-men as well as their own. Short time and high wages have done more to brutalise the miners as a class than any other improvement yet. Because some idle men who will not work, and are anxious that others should not do so either, chose to affirm that the miner was insufficiently paid. The owners are compelled to pay a price for labour that is quite incompatible with any successful attempt to compete with foreign countries.

It is quite impossible that any real improvements can take place in trade whilst the producers of the coal and iron required are compelled to pay this excessive demand. It would be all very well if the miner were the better for the increase of wages, but he is not; and we think that magistrates will agree with us when we say that the higher the wages the more men are brought before them for drunkenness, rioting, etc. It is nonsense to suppose then that any expensive appliances can be added to mines whilst the question of capital and labour is still in such an unsettled state; and the miners themselves will suffer in the end, as good ventilating appliances can benefit only them, not the owners.

A short time since it was sought to introduce a Bill the object of which was to compel the employer of labour to compensate those he employed for any injury received in his employment. Any scheme of this kind has two sides to the question. It would very shortly undo all the good that provident societies have done for the last fifty years, and would be the means of preventing workmen from saving any part of their wages against accidents or a rainy day. It would largely increase the recklessness of life already exhibited by workmen, and in many cases (if the Bill had passed) the workman who received his compensation would only spend it in drink and useless luxuries, instead of applying it to some means of gaining a living. But to return to the subject.

Another form of danger always present in a mine is the possibility of the ignition of coal-dust. Mr. Galloway wrote some very able and interesting articles in the journal 'Iron' on this subject. That such a thing is possible has been well established in France, and the only safeguard that can be seen at present is to keep the ways frequently wetted, though I fear there are many practical objections to this.

M. Guibal exhibited at Brussels a very excellent invention for measuring the variations of what the inventor calls the temperament of the mines, with a view of ascertaining what effect is being produced in a mine when increasing or lessening the amount of air-current. The adoption of this instrument in many of our English mines would be attended with good results.

In all mining operations, such as driving a heading, there is always considerable liability of heading out into an old working, or what Cornish miners would call 'holing a house,' with this exception, that the house may contain gas as well as water. Should such a thing as this occur the miner should not withdraw his rod, but report the occurrence without delay to the fireman or one of the deputies, who should take such measures, should gas be coming off from the hole, as shall effectually prevent the gas coming off in a greater quantity than the ventilating current will dilute and render harmless. This is easily done by partially plugging the vent after with-

drawing the pick or boring-rod; the gas would then come out in small quantities and be properly diluted and carried off.

Now, instead of taking such individual precautions as these, hewers very frequently go on with their work, quite ignoring the fact that the gas is issuing from the hole and assuming an explosive form by insufficient combination with the external air, until an explosion takes place. Now, the *absolute prohibition of naked lights* in coal mines would prevent all these classes of accidents.

Sump-holes, again, may cause danger, if not explosion, in the mines by gas escaping into them and being forced up into the mine by the water rising in the sump-hole. Great caution should always be exercised in opening and emptying them, and it is questionable whether it would not be advisable to have the lids with which they are fitted made of perforated iron, to allow the gradual escape of the gas. When the holes become full of water and it is necessary to empty them, their atmosphere should be carefully tested with a Davy lamp. If a lamp is used the glass may crack by a drop of water splashing on it, though the makers of this latter lamp would deny that it is possible to crack the glass cylinders with water when hot.

If such individual precautions as these were taken many accidents would never take place. Smoking in mines is still practised, though, I believe,

much less since the passing of the Mines Regulation Act. Many persons who are not connected with mining matters unjustly attribute each and every explosion to this practice, and I may here take the opportunity of stating that it is not at all a frequent occurrence. Since the passing of the Act it appears to be going out, and we may hope that miners have at last taken in the danger of continuing such a practice.

Now, the best method of preventing it is to prevent the possibility of a light being obtained. The public say that all the men going down the pit should be searched, and their view of the case, though practical, would be found very impracticable to carry out. It is impossible to search men for matches; it has been tried, and has failed over and over again.

Locked lamps will go a long way toward stopping smoking in mines, provided the locks are good. The very best locking for a safety-lamp is comprised in Bidder's patent electro-magnetic lock. It is very simple, cannot get out of order, and only adds about 1*s*. to the cost of a lamp. The lamp, when in normal position and screwed up, is locked, and can only be unlocked by means of a very powerful electro-magnet. It may be seen in operation at Harecastle Colliery, in North Staffordshire, where everyone testifies to its simplicity and security.

On examining the catalogue of ventilating apparatus for mines it is worthy of notice that the

majority of the inventors are Belgians—for instance, Guibal, Pasquet, Lambert, Lebnet, De Vaux, Hargé, Fabry, Lemielle, and many others; and ventilation by mechanical means is approaching a high state of perfection in Belgian mines. M. A. De Vaux, Inspector-General of Mines in Belgium, has devoted himself to a very interesting study of the instantaneous disengagement of gas in mines, for which the reader is referred to 'Annales des Travaux Publics,' T. xxiii., 1865.

Ventilation by compression was tried in France, at Blanzy, but the results were not satisfactory, so that we may conclude that the question resolves itself into diluting the gas when it has come out.

In the Yorkshire district, and in Wigan particularly, gas very frequently exudes in greater quantities and at a greater rate than an ordinary 'blower.' These outbursts are known to have been the cause of a great number of accidents. In the analyses of the Lancashire seams we find the percentage of hydrogen to be very much greater than in some other seams, such as some of the Welsh seams. The analysis of the Ince Hall coal, in Lancashire, gives the following proportionate composition:—

Specific gravity	1·348
Carbon	80·78
Hydrogen	6·23
Nitrogen	1·30
Sulphur	1·82
Oxygen	7·53
Ash	2·34

There is not the slightest doubt that these large blowers and outbursts of gas are caused by the gas being forced out by some pressure. Surface-water running through into the dip workings is a direct cause of outbursts of gas. There may be a fault or a cavity in the seam filled with gas; some slight movement of the overlying strata allows some water to run into this cavity, which it does by expelling the gas. If the water in the standage be allowed to get very high there is considerable risk of an outburst taking place. When a large blower of gas comes off where a fault is *known* to exist it is a good plan to drive a tube down into the fault, attach a pressure gauge, and (if the pressure is not excessive) blow the gas off gradually, and so allow it to become diluted; but frequently the outbursts are accompanied with such a pressure as to blow up the flooring, and so defy an attempt to restrain them.

The safest precaution is to withdraw the men and let the gas blow off, and lay on brattice. Air-tight lids to sump-holes, in our opinion, are in some degree conducive to outbursts such as we have described; if they were covered with an iron grating no harm could possibly arise when lamps are used. It is quite impossible to foretell an outburst of gas, and therefore precautions cannot be taken before it occurs to prevent it; in fact, if the gas *is* kept back in one place it will only blow off in another.

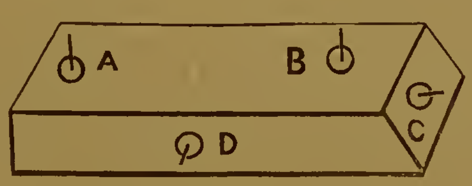
Near a fault, blowers of gas may always be ex-

pected. We have seen (in the Cannock Chase coal-field) the gas blowing through the road on the surface after there had been much surface wet, exactly under the spot where at about 800 yards, or perhaps deeper, a fault is known to exist. A very remarkable outburst of gas took place some short time ago at Barnsley, at the Oaks Colliery, belonging to Messrs. Cammell & Co., and formed the subject of an interesting Paper read before the Midland Institute of Mining Engineers.

The danger in an outburst of gas consists not only in the presence of a large quantity of gas that is not sufficiently diluted with atmospheric air to render it harmless, but also in the rate per second that the mixture impinges on the gauze of the safety-lamp. I believe that the real danger in 'shot firing' in fiery mines is more easily accounted for by the following theory than by the supposition that the gas becomes ignited by the flame of the shot. The explosion of a shot causes, in the first instance, a great wave of air, whose particles are in a violent state of commotion, to pass up the heading.

We have seen the flame from a safety-lamp 'jump' when a shot has been fired at a considerable distance off. An hydrogen flame is sensitive to vibration and musical sounds. This is merely due to *vibration*. It is perfectly possible that the wave of air and gas may meet the lamp at a high velocity,

and so pass the gauze, but in our opinion it is desirable that a series of experiments be carried out to ascertain how far *vibration* affects gas outside the gauze of the lamp. It is highly probable that the gas, being thrown, as regards its particles, into a violent state of vibration, may pass the gauze and so cause explosion. If this be so, it would be necessary to determine how far from the explosion the effect on the lamp will be produced, and to ensure that before firing a shot the lamps are withdrawn to the prescribed distance. There is one point that is often overlooked in making calculations and in general mining operations, namely, the elasticity of air. A mine is filled with an elastic fluid, and if pressure be applied at any point on that fluid it will exert itself equally in all directions. There is no difference between the elasticity of air and that of water or gas as regards the property of conveying impulse, and the simplest method of determining this property will be found in the following, taking water as an example :—



The above figure represents a closed vessel. A, B, C, D are apertures fitted with pistons. If the vessel is filled full of water, and the pistons main-

tained by a mechanical contrivance in their respective positions; if one of them be pressed with a force P it is found that the others (by means of the elasticity of the water) require a force P to be applied to each of them to make them retain their places. If the area of the piston is 1 square inch, and P = 1 lb., then 1 lb. of pressure is experienced by each square inch of the vessel's surface. If A and B, the areas of whose lower surface are α and β respectively, be two pistons fitted into the upper surface of a vessel filled with water, and if Q be the pressure experienced by B when a pressure P is exerted on A, then $Q : P :: \beta : \alpha$. For, in consequence of the pressure upon the piston A, a pressure P is transmitted to every portion of the surface of the vessel whose area is represented by α, and therefore to every unit of area a pressure is applied equal to $P \div \alpha$. Since the lower surface of B contains β units of area, the whole pressure experienced by B is $P\beta \div \alpha$. And Q denotes this pressure.

$$\text{Therefore } Q = P\beta \div \alpha.$$

$$Q : P :: \beta : \alpha:$$

$$\frac{\text{pressure on B}}{\text{pressure on A}} = \frac{\text{area of B.}}{\text{area of A.}}$$

If the lower surface of the piston A be a circle with a diameter of 1 inch, and that of B 1 foot in diameter, then, as in the case of the

$$\frac{\text{area of B}}{\text{area of A}} = \frac{12^2}{1^2} = 144;$$

and therefore

$$\frac{\text{pressure on B}}{\text{pressure on A}} = 144$$

$$\text{pressure on B} = 144 \times \text{pressure on A}.$$

So that if a weight of 1 lb. rest upon A, a weight of 144 lbs. must be placed on the piston B, to maintain equilibrium. We propose to apply this to the question of the closing of sumps and its effect on outbursts of gas.

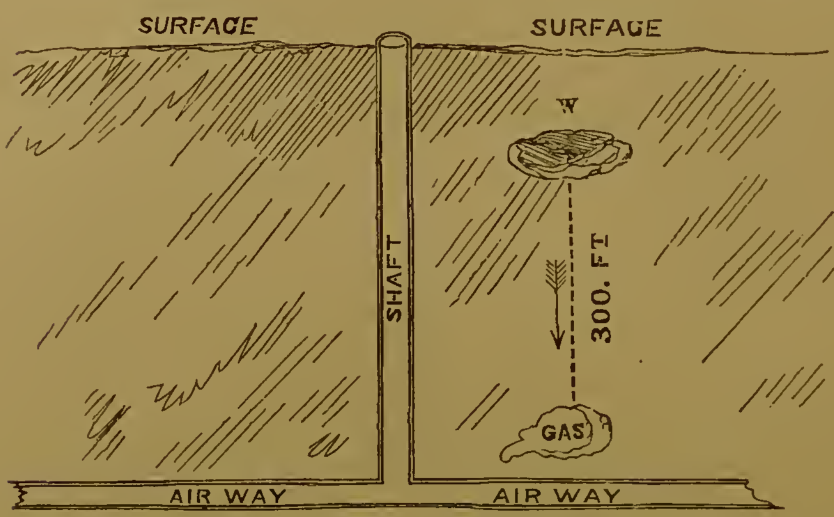
If the sump be A, and the pressure in it be 1 lb., owing to the rising of the water, then 1 lb. is transmitted to the water, and from the water on to the gas in the cracks in the seam and strata in which the sump-hole stands; then the gas will transmit the pressure until it meets with a large body of gas in the seam, with perhaps twelve times as much surface area as that of the sump A.

This gas is pressed to 144 lbs. and blows out.

The relation of the barometrical reading and consequent atmospheric pressure on the square inch may just allow the gas to stand pressed at 144 lbs. at 30 inches of mercury; when the barometer falls to, say, 29·00, 1 lb. of pressure is lost, and out comes the gas into the mine. Then, if my theory is correct, we should either leave our sump lids off or make the sump-hole water-tight. The former is the cheapest and simplest method of meeting the difficulty.

The figure represents a section of a mine; W is

a body of water; G a body of gas. If the water escapes, it will ultimately force its way into the space G, blowing the gas into the airway. Let us assume that the distance W G is 300 feet. Then the question resolves itself into the weight of a column of water 300 feet high, resting upon a body of gas at G, which is at liberty to escape under favourable atmospheric conditions. Thus it will be seen that an approximate idea both of the cause and its locality can be



reached when the blowing off pressure of the gas has been ascertained. Supposing a column of water of 300 feet to weigh x lbs., then we shall find the gas blow off with a pressure of 10 lbs., and we have only to consider what weight a column of water must be to weigh x lbs. I do not say these are the causes of every blower or outburst of gas in coal mines, but I merely wish to call the attention of those engaged to the mutual relations which exist

between the two cases. There is no doubt that water *must* be the primary cause of blowers. The question is, *is the water surface water, or is it pressure in the sump or standage?* The existence of the latter can be both ascertained and prevented, and the absence of the latter proves the existence of the pressure in many cases.

Gas may be confined by a shifting roof and be compressed to a great extent, and on liberation appear in the form of an outburst or blower.

What we require, and to what we wish to draw the attention of our mining engineers and others, are :—

1. Good and effectual means of preventing the air and the fire-damp from forming in an explosive proportion.

2. The absolute prohibition of naked lights, and the compulsory use of locked lamps of the best form.

It would greatly lessen the annual number of accidents if some experiments were tried with the various explosive compounds, with a view of ascertaining whether they are all equally liable to ignite an explosive mixture of fire-damp, for I believe that, on experiment, gun-cotton would be found less liable to explode gas or fire coal-dust than gunpowder.

The temperature of a mine is an important item to be considered in making arrangements for ventilation, for it may alter the direction of air currents,

and so detract from its efficiency. In all trials of ventilating apparatus the temperature of the different parts of the mine should be taken into consideration, and this is not always done.

Under the heading of gas we come to another difficult question, what form of lamp combines with safety the maximum amount of light and high sensibility as a testing lamp? We will, therefore, enumerate the different classes of lamps in use in coal mines, with a short description of their several properties and the especial merits which each separate inventor claims.

CHAPTER VII.

THE DIFFERENT FORMS OF SAFETY-LAMPS, AND THEIR RESPECTIVE MERITS AND FAULTS.

THE lamps in use at present are :—

The Davy lamp.
Stephenson's lamp (Geordie lamp).
Clanny lamp.
Morrison lamp.
Mueseler lamp.
Watson & Lambert lamp.
Watkin & Evans lamp.

The Davy lamp is in use in the North of England by all classes of miners. It is provided with a single gauze and shield. An explosive mixture of gas and air meeting the lamp at a velocity of about 8 feet per second will pass the gauze and become ignited. Its illuminating power is not very great.

A modified form of the above has a glass cylinder round the flame, protected by vertical metal bars. Another modified form of Davy lamp has a single copper gauze, shield, and bulls-eye, and is known by the name of the 'Copper Davy,' and is used in surveying and dialling.

The Stephenson (Geordie) lamp is in use in Yorkshire, and, as manufactured by Messrs. Mills & Co., consists of a flame surrounded by a glass, which is surrounded by gauze. An explosive mixture with a velocity of 9 feet per second meeting the lamp will pass the gauze and become ignited. The illuminating power of this lamp is, perhaps, more than that of the ordinary Davy lamp.

The Clanny lamp, invented by Dr. Clanny, has a glass cylinder of about 2½ inches diameter round the flame, which cylinder is protected by vertical bars and surmounted by a gauze cylinder, forming the chimney of the lamp. An explosive mixture passing the gauze at a mean velocity of 9 feet per second becomes ignited. This class of safety lamp is very much used in Yorkshire and Northumberland by stonemen and waggon-way men, the hewers gene-

rally using the ordinary Davy lamp. It has a very fair illuminating power, and has been modified to burn mineral oil, such as benzoline.

Morrison's safety lamp has a double glass, with internal chimney, and though a good lamp is little used or known.

The next form of lamp we come to is the Mueseler lamp. It burns vegetable oil, and its use has (since June 17, 1876) been prescribed in all mines in Belgium. It has stood very severe tests, and is considered by foreign engineers to be the best lamp yet invented. It requires an explosive mixture of fire-damp to possess a greater velocity than 24 feet per second before it can pass the gauze of the lamp, and so become ignited. It is constructed with a glass cylinder and internal cone, with a gauze over the top of the glass. This is the type recently authorised by the Belgian Government. Its illuminating power is very good, and it is to be regretted that it is not in more general use in England. It is the lamp that most nearly meets all our requirements; and if fitted with Bidder's patent electro-magnetic lock would be found to answer better as a safety lamp than any lamp in use in England.

The Watson & Lambert type of safety-lamp is constructed with mica plates, gauze, and cone, and is characterised in the catalogue of lamps tried by the Committee of the Mining Institute at Newcastle-

on-Tyne as being unsafe. It was in use, but has been since entirely withdrawn.

The lamp associated with the name of Messrs. Watkins & Evans is also condemned as being unsafe.

It would thus appear that the Mueseler, Clanny, Stephenson, and Davy are in their order the four best lamps to use. A serious objection to glass cylinders surrounding a flame is their liability to crack if hot and exposed to drops of water. Mr. Hall, the engineer of Haswell Colliery, refused to allow their use for this reason only, I believe, and has only the Davy lamp. A lamp-cleaner at Harecastle Colliery denied that they would crack, but a private examination of the lamp-room disclosed two glasses cracked completely through.

Mineral oils as a lighting agent are objectionable, though economical.

A lamp was on trial in Dudley which was extinguished on opening it, but such mechanical arrangements are not always required for a safety-lamp.

Persons traversing a mine who meet the air-current should be careful to lower the shields of their lamps; but this precaution is frequently neglected. Everyone connected with a coal mine should be made well acquainted with the behaviour of the flame of a safety-lamp when influenced by gas, and miners should be examined from time to time on this point.

A quick and simple manner of testing the efficiency of the gauze of a safety-lamp is to turn a

jet of gas inside the gauze cylinder and apply a light outside; if the flame passes through, the gauze must be defective, and should be condemned as useless. It is not desirable that the miners should take their lamp-chimneys home to clean them, as is commonly done; it is a temptation to the miner to make a hole by which to obtain a light for his pipe.

The locks supplied with the Clanny lamps are in themselves a temptation to the miner to unlock, and should never have been permitted in mines at all; they are clumsy, and liable to get fast if screwed too lightly, and are altogether useless if not screwed up enough.

We must in conclusion express the hope that the Mueseler lamp will at some future period be more generally used in England. I have tried a number of experiments with it, and it appears to deserve all the merits the inventor claims for it. I obtained one explosion with it at 22 feet per second, but the flame was rather higher than it should have been according to the instructions.

Some time since I witnessed some experiments in the lighting of mines by means of an electric light; the result was far from satisfactory, for when meeting the light its intensity dazzled the eyes, and when walking away from it the shadows were very intense. From an optical point of view it would be objectionable, as the eye could never become accustomed to the rapid change from intense light to

darkness. If any electric light is used, Gramme's will be found the most suitable for this purpose.

Mr. Brown (Stoke-on-Trent) states that it would be conducive to greater safety if mines were so laid out as to be worked with naked lights, by having three or four air-shafts in place of two. Anyone who has worked in the Barnsley seam will see at once the absurdity of the statement, as outbursts of gas such as occur in that district would blow up the pit if naked lights were used.

CHAPTER VIII.

SPONTANEOUS COMBUSTION AND GOB-FIRE.

The tendency of coal to ignite spontaneously has of late occupied the attention of shippers more than that of the owners of mines. Certain sorts of coal are much more liable to heat and generate spontaneous combustion than others; for instance, coal that contains sulphur or iron pyrites. The miners call this class of fire 'gob-fire' or 'breeding fire.' A common cause of spontaneous combustion in coal not usually given to ignite is the friction of the roof pressing on the seam and igniting the shale by the heat developed. The effect of a gob-fire in a mine is

to raise its temperature, and consequently to interfere with the quantity and direction of the air-current, and so upset all the arrangements for ventilating the mine.

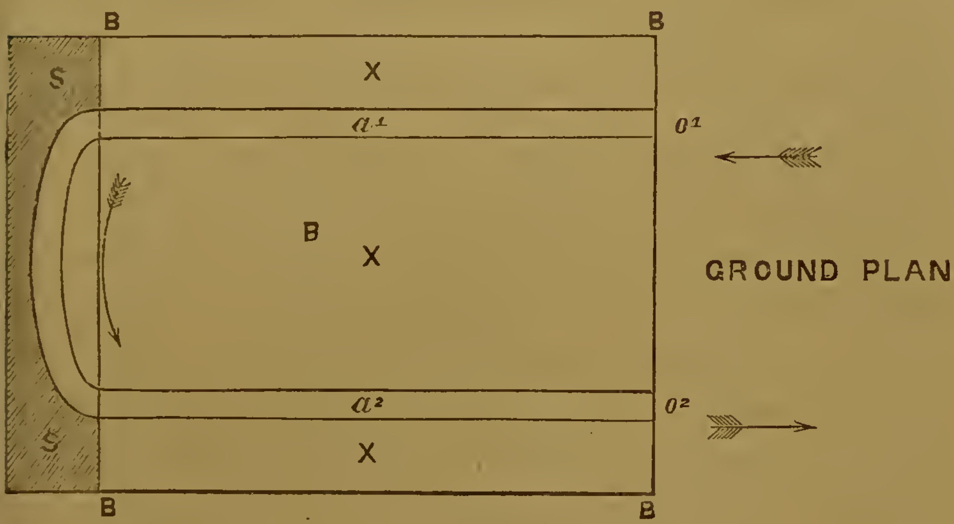
Gas is frequently given off, and a peculiar sulphurous smell, known technically as 'gob-stink,' pervades the whole region of the mine in the neighbourhood of the gob-fire. Anyone desirous of going further into the matter will find full particulars in the Report of Her Majesty's Commissioners appointed to inquire into the causes that lead to, and means of preventing, the development of spontaneous combustion in the holds of ships laden with sea-coal—the Report as laid on the table in July 1876.

An excellent instance of the damage gob-fire may do is that of the gob-fires at Harecastle Colliery, the property of Sir George Elliott. The seam in which the fires occurred was not generally supposed to be liable to spontaneous combustion until it broke out a few years back. Mr. Wilkinson has taken every precaution to ensure the safety of those working in the mines, and a constant watch is kept on the suspected place. Whenever a fire occurs stoppings are at once put in.

Collieries in Sutherland, the property of the Duke of Sutherland, are also more or less liable to gob-fire. A watch is kept in this by means of a patent safety indicator, which telegraphs a warning to Mr. Edwards, the manager, if the gob is heating.

The best form of stopping gob-fires is a wall 1 foot thick of brick, then a space of 3 to 4 feet filled with sand, and then another wall of brick 1 foot thick. The faces of the two walls should be well cemented over, to exclude any air.

The following is an excellent method of working a seam liable to gob-fire :—



Let us suppose B, B, B, B represent the block of coal to be taken out. We drive a^1 and a^2, two parallel airways, into the block B, and provide them with air-doors, o^1 and o^2, made air-tight and tolerably fireproof. Patent thermometers, as supplied at Bora Colliery, are placed at the points marked X, and the indicating wire led away through the airway marked a^1 to wherever the alarm station is situated. The airway a^1 is intake, that marked a^2 forms the return airway ; S S are the extremities of the stop-

ping. Now, if the block B heats the thermometer, X will give us an alarm before any damage is done. We then shut the air-doors marked o^1, o^2, and the fire is struck out, notice of which we get on the safety indicator in our alarm station. It is proposed that this plan shall be carried out at Harecastle Colliery.

In all cases where gob-fires are known or even suspected to exist a careful observation should be made daily of the barometers, thermometers, and water-gauges, and if the gob-fire can be localised it should be stopped off at once and prevented from consuming the air required for the proper ventilation of the mine. It might not be out of place to mention here that Tyndall's Respirator is an excellent preventive against the evil effect of gob-stink, and it enables the wearer to make a thorough examination of the locality. In mines liable to gob-fires at least twelve of these respirators should be kept at the pit, in order that they may be available in case of accident. Many valuable lives might have been saved had this invention been more known and its merits appreciated. An adequate supply of materials for stopping-off should always be near at hand. The existence of a gob-fire in a mine must naturally always be an anxiety to the engineer in charge, and we should, therefore, be always informed of any change that may take place in the affected part of the mine. One of the worst features of gob-fire is that gob-stink is but seldom perceptible until

the breeding fire has actually set in, and many engineers do not recognise the presence of a gob-fire until the unmistakable smell is given off. It is then too late to take precautions; nothing remains but to stop off the fire. The system of extinguishing by means of the 'Extincteur,' carbonic acid gas, and all chemical fire-engines, is merely a loss of time and money.

A serious case of gob-fire occurred at Lilleshall Colliery in September 1875. Eleven men lost their lives by encountering the deadly gob-stink, which in that case was no doubt largely impregnated with choke-damp. I refer the reader to the official report of the Mining Inspector of the district to judge whether due care was exercised in that particular case.

In all cases where it is necessary to ventilate a mass of coal which is liable to spontaneous combustion, the following should be carried out:—

Superficial ventilation only should be employed to carry off the foul air, and on no account should air be forced or allowed access to the interior mass of coal. In most cases the coal only requires oxygen to cause spontaneous combustion to set in. Vessels carrying coal should be properly protected with thermometers, and should be built for the purpose for which they are intended. The chemical causes of gob-fire have been considered fully further on, both as regards mines and ships.

Explosions of gas in mines may occur through neglect of shutting doors erected for the purpose of controlling the air-current. L. Brough, Esq., one of H.M.'s Inspectors of Mines, mentions a case in his annual report which proved fatal to all present. It occurred at Cwm Tillery Colliery, on April 5, 1873, in the South-Western district, and was without doubt due to leaving down the air-sheets.

The position of every important air-door in a mine might be constantly ascertained by electric indicators, such as are supplied to the distant signals on the London and North-Western Railway, known technically by the name of Electric Repeaters.

Accidents arising by inundation from water are now happily rare, and, owing to the excellent machinery and pumping arrangements of the present day, we may hope out of date, or at all events of but rare occurrence.

CHAPTER IX.

PRECAUTIONS THAT MIGHT BE TAKEN AFTER AN ACCIDENT.

There are very few collieries in England that have *ready at hand* any medical appliances for use after an accident has occurred. That this should be so is to be regretted more and more every year. We know

that accidents will occur in spite of every precaution, but we surely cannot be justified in neglecting to provide means of rescuing the sufferers or treating them after it has occurred. Lint, sweet-oil, splints, a litter, Tyndall's respirator, brandy, should all be kept in the pit. Anyone who would draw up a set of directions in plain English for the treatment of burns, suspended animation from after-damp, etc., would do much more good in circulating them in the mines than those indefatigable people who write to the 'Times' and air their ideas on every occasion and on every subject. The Royal Humane Society has done so in the case of persons found drowned with admirable results; let us hope they may be induced to do so for the miners.

Of late some little attention has been paid in Belgium to the various appliances for enabling a gang of relief men to breathe pure air whilst endeavouring to rescue those who are injured by explosion or choke-damp. Foremost amongst the inventors of apparatus for the accomplishment of this object we find the names of MM. Galibert, Denayrouze, and Fayot.

The apparatus of M. Galibert is the following:—The explorer carries on his back a reservoir of air at the ordinary pressure, into which his exhalations are sent back. This apparatus has many grave defects. It is too heavy and cumbersome to enter workings with after an explosion.

M. Fayot's apparatus is open to the same objections.

No arrangement requiring an air-pump is of any practical use in close headings.

M. Denayrouze's apparatus is used by means of compressed air, and is illustrated in Chapter XVIII.

M. Schwann has brought out an excellent apparatus, exhibited in the Brussels Exhibition of 1876. The principle is the regeneration of atmospheric air by the absorption of carbon dioxide and the addition of oxygen in the liquid proportions. With this apparatus a man may breathe for a space of two hours without inconvenience, and the apparatus is not inconveniently heavy.

M. Schultz has another form of this apparatus, in which the air for respiration is produced by permanganate of potash and acetic acid.

These last two inventions are well worthy of further consideration and practical trials.

No air apparatus requiring any great length of guttapercha tubing is suitable for a mine, on account of the loss of time in retracing ground already passed over, and for many other reasons too evident to require further explanation. The importance of having immediate access to means of saving life after explosions in mines is not half sufficiently recognised in this country, and it is to be hoped that coming years will produce more perfect appliances for this object. In Chapter XVIII. will be found plans

and descriptions of two very excellent inventions of M. Denayrouze, of Paris, a well-known submarine engineer.

CHAPTER X.

THE GROWTH OF THE ROYAL SCHOOL OF MINES AND ITS RELATION TO THE EDUCATION OF MINING ENGINEERS.

One hundred years ago any man who had the slightest appearance of possessing the rare gift of the power of managing men, and who possessed some influence with the leading shareholders of a colliery company, in due course of time became a manager or the engineer of the mine in which he was employed. His only idea was, probably, how to raise coal quicker and with least expense, and to ensure, if possible, a minimum of the fatalities which occur in mines. If he killed fewer people than the manager of the mine next him, then he was a better engineer, and the public were satisfied. If he knew but little about ventilation, it was nobody's business to require that he should know more.

But in course of time the public began to ask whether any steps were being taken to reduce the average of lives lost for the amount of coal raised. It was not considered sufficient that he should satisfy the company who employed him, it was decided by the public that he must also satisfy them. Perhaps this change was due to the introduc-

tion of cheap and daily papers and the reduction in the postal charge for letters. People began to write and ask how such and such an accident happened; the papers had a short article on it, and ideas were exchanged about it. Perhaps a question was asked about it in the House of Commons.

In order, therefore, to satisfy public opinion it was necessary that a mining engineer should be specially educated in the more scientific part of his profession, and that to ensure this some sort of diploma or certificate of proficiency should be granted to him, as is done in the medical profession, and that he should not be allowed to practise without this guarantee.

With a view to effect this and to meet the requirements of the time the Royal School of Mines was established, in Jermyn Street, London, where lectures specially bearing on mining matters are delivered at a moderate charge to those desirous of attending; and chemistry, mechanics, and geology were considered necessary subjects for a mining engineer to study.

An Act of Parliament was then passed entitled the Mines Regulation Act. This Act prohibited a mining engineer from managing a mine unless he held a certificate of proficiency. Inspectors of mines on behalf of the Government and the public were appointed, and a clause inserted in the Act to enable those employed in mines to call for an inspection,

made at any time, at their own expense and on their own behalf.

The inspectors nominated by Government were all competent men, and capable of managing a mine themselves at any time. The present arrangements of the School of Mines consist of courses of lectures open to all at a moderate scale of charges; the opportunities offered by a first-class geological museum and laboratory, to which are attached able practical chemists, metallurgists, and mineralogists in Dr. Percy, F.R.S., and Professor Warrington Smythe, F.R.S., to each of whom I am greatly indebted for much useful information. Another great advantage consists in the proximity of the Mines Record Office, under the able directorship of Robert Hunt, Esq., the keeper, to which office all interested in mining operations may have access, and where detailed accounts of borings executed in Great Britain in search of minerals may be obtained, with excellent plans and sections.

This department in itself has saved much valuable time, labour, and capital. In years back many searches for minerals have been made which merely resulted in great and fruitless expenditure of capital, for want of such information as this department now affords. The Geological Museum is open to the public on certain week days, and many persons avail themselves of this opportunity of studying the various materials brought up from the bowels of the earth.

We may congratulate ourselves on the success of this national institution, for in coal and iron lies our principal wealth in this country. The idea of giving a sound practical education to persons intending to follow this special branch of engineering has been well conceived and still better carried out; the results we see every day in the new and improved appliances for the better and safer working of mines.

Some people may say that the examiners grant a certificate of proficiency as far as regards the actual knowledge of the subject, but that, although men know what ought to be done and how to do it, yet in many instances they are unable to give an order to others to do it, when, no doubt, they are well able to do it themselves. To raise this objection is mere fault-finding. To give a clear order, intelligible to all, requires the experience of a lifetime, gained by practical knowledge of the subject; and if that knowledge is to be gained anywhere it is to be gained at the Royal School of Mines.

CHAPTER XI.

BOILER EXPLOSIONS.

We have considered most of the causes which lead to the loss of valuable lives in mines; we have suggested systems and regulations with a view to

lessen that loss. Whether they will meet with the approval of those who have to deal with the questions is impossible to decide. Much time and money is frequently spent by inventors in trying to introduce new appliances, but in many districts custom and prejudice forbid their introduction.

It is to be regretted that in this country Government takes so little interest in inventions for the saving of life. The National Lifeboat Institution owes its origin to the energy and enterprise of private persons, backed by the advice and assistance so generously afforded by the late Duke of Northumberland. What it started from and what it has risen to is a history in itself. Now there might be a proper system organised for the fair trial and examination of apparatus for use in mines; for instance, in the Forest of Dean, where the Crown owns coal mines. The expense (if the trial proved successful) should be defrayed at the public cost, for who are those who benefit most by the introduction of valuable inventions, such as steam, the electric telegraph, etc., but the public? Where would our national wealth be but for such inventions as Mr. Bessemer's for the conversion of iron into steel?

It is one thing to possess coal and iron, but the secret lies in knowing and applying the most economical and safe methods of working them to advantage. The conversion of the Cleveland iron into steel at a low cost is one of the most important matters

for engineers to consider. Now that steel rails are so universally used for railways, unless we can convert the iron of that particular district into steel, we may reasonably expect a falling off in the exports of that particular class of manufactured article, and an increase of foreign competition. It is, however, open to doubt whether the latter is injurious to ourselves as a nation, for it no doubt stimulates both masters and men to put forth all their energy to be first in the market.

Now, a pecuniary grant from the nation for a series of experiments on the Cleveland ironstone would, no doubt, enable many to invent a simple process to effect this conversion, but such a grant at present has not been made. So it is in the case we are considering, viz., *the prevention of accidents in mines*: we need a grant or some encouragement from the nation for perfecting our appliances for raising coal and iron with fewer accidents to those employed. Every miner who is injured is a pecuniary loss to the country. An able-bodied man is perhaps made a cripple for life; his expenditure in food and clothing is the same, and he does not add to the wealth of the nation. Our country is so small in extent that we cannot afford to keep men who are unable to work. The Belgian Government are at present giving a great deal of attention to the safe working of their minerals. They have far stricter rules and regulations for the working of mines than

we have in England. If an invention is good and would tend to lessen accidents an order goes out for its adoption, as in the case of the Mueseler lamp and the Guibal fan.

The method of signalling known as 'hammer and plate' is a clumsy, unsafe system that should have died a natural death long ago; but it still goes on in some districts. There is no doubt that next after good ventilation and hauling appliances comes a good system of signals; this latter we have in the electric block signalling bells.

Much attention is given to and stress laid on the effectual locking of safety-lamps, while by simply drawing the wick (with the pricker) above the gauze and canting the lamp to one side, a miner may light his pipe with ease.

The practice of putting back slack coal into the waste is a bad one, and on no account should a naked light be allowed in the waste. Slack coal, when much broken, has a tendency to heat and ignite spontaneously, and many gob-fires might be prevented if this were more attended to. The model of a well-managed and equipped colliery may be seen in the Cannock and Rugeley Colliery Company's Pool Pits, at Hednesford, where, under the management of Mr. Williamson, both the safety and the comfort of the men is the first thought of the owners. There, if gas has been found in any heading, a plain notice is posted, intelligible to all, stating that if either

naked lights or tobacco are used beyond the notice the user will be summoned before the magistrate for a breach of the rules. The winding ropes are provided with an excellent detaching hook and safety break. The signals are of a peculiar form, and are electric. They are so arranged that no contrary signal can be given. The ventilating fans are well worthy of notice, the water-gauges being in the engine-room. Even the wheels of the tubs are automatically greased! Many persons may say that all these dodges and *contrivances* fail, but the fact remains that this particular mine is as good a paying mine as perhaps any in the country.

Accidents occurring through falls whilst holing might easily be prevented if a responsible person were told off to see that the hewers put in sprags when they have undercut, say, a distance of three feet.

Large quantities of timber are imported annually from Norway to be converted into pit-props. Railway embankments are well suited for growing this class of timber, and it is surprising that the cultivation of these embankments is making so slow a progress. In many mines it will be noticed that the store of pit-props is not sufficiently near at hand; though many collieries, on the other hand, make a particular man responsible that a proper supply is kept available for use.

We have omitted to consider a class of accident

not unusual in mines, but generally on the surface, namely, boiler explosions. The remedy against old and defective steam boilers is to insure them in the Manchester Boiler Association. The remedy against incrustation is to blow them off and clean them regularly. But here we come to a subject the importance of which we do not think is sufficiently considered or realised. It is a common practice to blow off the boilers through the scum-cock or other outlets before the water is sufficiently cool; the consequence is that in a boiler of considerable longitudinal section, such as an egg-ended boiler, an appreciable contraction takes place in too short a time. This exposes the seams and rivets to considerable strain, and cannot be otherwise than very detrimental to the strength of the boiler.

The water should never be blown off until it has cooled to a temperature of at least 150° Fahr. Hand-lifting safety-valves are very deceptive in their action where a set of boilers are in use and the stop-valves are open. They should be lifted every morning when getting up steam, and also in the course of the day, if it is thought requisite. These little matters cannot well be made the subject of a general order; a careful and attentive engine-man will attend to them, and an idle man will not. In some collieries an objectionable, though well-meant, plan is carried out of connecting all the safety-valve blow-off pipes into one exhaust-pipe. If this is done an extra

valve should be provided, to indicate if the pressure is excessive, as the steam-indicating gauges cannot always be trusted.

The following form of boiler explosion sometimes occurs. Perhaps the engine has been standing and the safety-valve has been seen to act properly; on starting again the boiler explodes or is considerably strained. This may be explained thus: water boils under ordinary pressure (15 lbs. per square inch) at 212° Fahr. The greater the pressure the higher is the temperature required to convert it into steam. For instance, if the barometer read 30·516 the boiling-point of water is 213° Fahr.; if it reads 32·350 the boiling-point of the water will be 216° Fahr.; but if the atmospheric pressure can only sustain the mercury column to a height of 28·183 inches water will boil at a temperature of 209° Fahr., or 3° below the average boiling-point.

Thus we see that if anything should occur which prevents the proper escape of the steam when the engine is standing, the water is raised to a temperature above that required to form steam, but the steam cannot be formed, on account of the excessive pressure, or if any is formed it is not formed in any proportionate quantity. On starting the engine we suddenly lower the pressure, and a large bulk of steam is formed, which is quite out of all proportion to the capacity of the boiler; this may happen two or three times, but in the end it is sure to try the boiler severely.

It is necessary, therefore, to run the steam down well below the point where the safety-valve will blow off, before bringing the engine to a stand. This may be very easily done where colliery winding engines are concerned, as they generally cease running at a given hour. A very common but erroneous impression exists among engine-men that if the bottom of an egg-ended or Cornish boiler is well covered with water, although it may be thin at the bottom, the boiler is nevertheless safe. This is not so, for the boiler under pressure has a tendency to lift from its bed, and will take the form of a semicircle if the bottom seam comes unriveted.

Great care and attention should be paid to the quality of water used for feeding boilers. In some mines water containing lime, etc., is used for this purpose, and which is contaminated by mine drainage water. In multitubular boilers the system of leaving the fire-doors open to lower the steam pressure is highly objectionable, as (by creating unequal contraction) it tends to cause the tab-bolts to allow the boiler to leak at the extremity of the tubes in the fire-box end, and so establish corrosive action. With proper care boilers should not explode, and we cannot too earnestly impress upon users of steam (*a*) the wisdom of insuring their boilers against explosion; (*b*) the necessity of having all stop-valves and blow-off cocks marked legibly, to show their position, whether shut or open, at once.

CHAPTER XII.

THE USE OF BLASTING POWDER IN FIERY MINES.

We will carefully go into and consider the use of explosives in mines, since it is a subject of the greatest importance, and much good might be gained by carrying out a series of experiments with a view to ascertain what is the best explosive compound. In a preceding chapter we have considered each compound, weighed its merits, and compared its results. It would appear that for force, rapid ignition, and safety when stored, gun-cotton in its various forms stands first on the list of these explosive compounds.

The tools made for blasting purposes in mines are now manufactured expressly for the purpose. They contain an admixture of copper, and their composition is such that they will nots trike a spark whilst tamping or ramming home a charge of gunpowder in a shot-hole. It is made compulsory by law that only the special class of blasting tools be used in mines, but in sinking operations—in search of water, for instance—those in charge are at liberty to use what tools they like. Perhaps the butt end of a crowbar answers the purpose and is used safely for a long while, till at last a spark is struck and an accident is the result.

We would refer, as an instance of utter recklessness of life, to the negligent manner in which some blasting operations were carried on when driving a heading in search of water at Shanklin, Isle of Wight, in July 1876. In this particular instance the heading of about 4 ft. by 5 ft. dimensions was being driven horizontally into the hill. Two men were employed at work there, and were permitted to blast in the 'face,' using steel tools and naked lights. When a shot was to be fired in the 'face,' having lighted the fuse, they retired some little way back and waited for the shot to explode, remaining in the heading. Had one of these shots 'blown out,' as it is technically called—that is, had the tamping been inferior or the rock been too hard for the powder to split—the probability is that some loose rock would have been blown directly down the heading to where the men stood.

When charging the hole one man held a lighted tallow-candle whilst the other poured the powder into the hole, and by way of explanation they stated that there was no danger in the operation, since the man who had the powder canister did not hold the naked light. Every shot that missed fire was duly drilled out with a steel tool. It is needless to remark that the work was being carried on by a local Government Board.

Miners have to congratulate themselves that they are legally prohibited from doing this, as the

use of the steel tools in mines for blasting operations is productive of many an accident. The advantages of gun-cotton do not appear to be fully appreciated. Without doubt it is the best explosive for this purpose, and if the demand was greater it could no doubt be produced at a cheaper rate than at present. It can be stored wet, and is as good as ever when dried; it can also be ignited when wet. The practice, so expressly forbidden in the Mines Regulation Act, of unramming shot that have missed—*i.e.*, that have failed to explode—will never be thoroughly knocked on the head so long as stall-men find their own powder.

Common sense points out this; for supposing a miner to have charged a hole with two pounds of powder, and if on lighting the fuse it fails to explode, it is not likely that a working-man will lose the cost of that powder, when by simply breaking the law he can save it. Nor will he perform a piece of work for 1*s.* 4*d.*, when he can do it for eight-pence. Now, gun-cotton may be unrammed with ease and perfect safety, and by its use the question of unramming shots would be set at rest for ever.

Dynamite is quite unsuited for mining purposes as an explosive, not on account of its supposed uncertain behaviour, but simply because it requires to be in the hands of more intelligent and scientific men than those who ordinarily have to use explosives in mines.

In all blasting operations nothing but closed safety lamps should be permitted, and if gunpowder is used precaution should be taken that the canister in use should be kept isolated from any small store that may be required later on. Loose powder should, if possible, be got rid of, either by firing it or sweeping it away.

As an instance of recklessness of miners, affecting the safety of others as well as themselves, we extract the following from Mr. Bell's report in 1873:—At Ince Moss Colliery a man lost his life by unramming a shot, and the report goes on to say: 'Deceased was the man in charge, and had been frequently cautioned by the manager against drilling out missed shots; he, however, seems to have disregarded all instructions, and was sitting over and drilling out a shot, when it exploded, blowing him several feet up the shaft, killing him at once, and seriously injuring three others who were working with him at the time.'

Certainly, with such a report as this before him, no one could recommend dynamite as an explosive suitable to the requirements of a mine. The question of the danger of unramming a shot-hole charged with dynamite or nitroglycerine has never been discussed, but I am of the opinion that the friction of the particles of rock left in the borehole might prove sufficient to develop an undue amount of heat, which, although not sufficient in itself to cause igni-

tion, and therefore explosion, would undoubtedly contribute largely to the danger of using such a compound as dynamite, by raising its temperature too high to permit of its withdrawal.

It is much to be wished that the Legislature would authoritatively lay down what explosives should be used in mines, and with what fuse; and that it should enforce more stringent rules with respect to the use of such explosives by incompetent men. It is not sufficient that the law should enforce the use of a certain sort of tool in blasting operations; it is now time that some definite instructions were issued with regard to the kind of explosive to be used. In 1876 we find the deaths from various explosives, besides injury to thirty-nine others, to be as follows:—

Gunpowder	32 deaths.
Fireworks	7 ,,
Dynamite	5 ,,
Tonite	5 ,,

Copy of further Report made by H. M.'s Inspectors of Mines relating to the use of Blasting Powder in Fiery Mines, the Secretary of State for the Home Department having referred back to them their collective Report of 1865 *upon this subject in order that they might consider the propriety of Legislation, or of making general or special Rules.* (In continuation of Parliamentary Paper, No. 417 of Sess. 1875.)

With reference to Mr. Cross's letter of the 14th instant referring to the Report of the Inspectors of Coal Mines of

July last relating to the use of blasting-powder in fiery mines, and requesting that the subject be again brought under the consideration of the Inspectors, and to furnish him with their opinion as to the propriety of further legislation, or the making of general or special rules to deal with the question of such use of powder in fiery mines—

After a long discussion of the subject a majority of the Inspectors were of opinion that some alteration of the law is desirable, but on endeavouring to determine what alterations should be made they could not agree as to detail.

The following two resolutions respectively were then agreed to by the Inspectors whose names are attached thereto :—

Firstly, Messrs. Wynne, Brough, Alexander Moore, and Wardell are of opinion that explosives should be prohibited in mines where safety-lamps are used, and that a short Bill should be introduced into Parliament to carry that into effect.

Secondly, Messrs. Dickinson, Evans, Willis, Wales, Bell, and Hall are of opinion that most of the explosions which have lately taken place are due to violation of the first general rule, want of discipline and precaution, and that in those instances where it is necessary to discontinue the use of powder there is adequate power under the present Act.

They give place to no one in their anxiety to lessen loss of life from explosions, but they find that in consequence of the wide difference in the circumstances of the inspection districts, and in the difference in the mode of working, system of ventilation, and discipline, it seems impossible for the Inspectors to hold an unanimous opinion upon the subject of recommending further restrictions as to blasting.

At present, where the mine is so fiery that, notwithstanding adequate ventilation, the issue of gas at the point of emission is so strong as to show a blue cap in the safety-lamp, the use of powder is prohibited under the 8th general rule, unless the ordinary work-persons are out of the mine;

and further, that no shots shall be fired unless it is safe to do so. The judging of the safety of the place where the shot is to be fired may in the first instance have to depend upon the judgment of the 'competent person' appointed for the purpose, but on its coming or being brought under the notice of the owner, agent, or manager, each of them becomes responsible for any contravention in this respect if it be continued.

JAMES P. BAKER,

Secretary Inspector for the Year.

CHAPTER XIII.

SUMMARY.

The points referred to in the preceding chapter as being the cause of loss of life and limb in mines have not been nearly sufficiently considered. Neither space nor time admits of detailed accounts in such a question as this.

In the chapter devoted to the meteorology of mines, and the very necessary precaution that should be observed in reading and carefully observing the barometer, thermometer, and water gauges, we expressed the opinion that in many mines cheap instruments are in use, and that to ensure safety it would be advisable to require a certain adequate standard of efficiency and delicacy. It would also appear that insufficient attention is paid to a low reading of the barometer at bank. In Chapter II. we

have considered the use of gunpowder in mines as a source of danger. A number of accidents occur annually under this head—some that with a little forethought and care might easily be prevented, and others that no human intelligence can avert. All the Mining Inspectors testify to the careless manner in which miners handle powder, and their reports show a long list of deaths under the head of 'shot firing.' We have fairly, we think, shown that gunpowder is not the most suitable explosive to use in collieries, and that at present gun-cotton or some such preparation of Pyroxiline is. A careful consideration of the nature of fire-damp is sufficient to convince any outsider that naked lights should not be used in coal mines, especially when blasting is going on in the 'face,' and that if possible these operations should be carried on when the shifts are being changed. That the miners should be relieved at bank is a matter of course, as the fewer the men in the pit the smaller is the probability of an accident.

Chapter III. has been devoted to enumerating (only in too insufficient a manner) the accidents that are constantly arising from mechanical causes. This is a point that should be gone into with the intention of going to the bottom of it. Miners are careless of the lives of others in their method of handling tubs, etc. Such a thing as leaving a tub on an incline with the wheels unscotched should not be tolerated by any manager.

Many mines are not provided with a sufficient quantity of man-holes with gate-roads, and the practice of making these refuges receptacles for rubbish should be stopped by fining. Surely this comes under the head of '*Dangerous practices not expressly forbidden in the Act.*'

Over-winding, as we have shown in Chapter IV., is undoubtedly due to the negligence and inattention of the engine-driver; but since engine-drivers are but human, it is necessary to provide some mechanical appliance to prevent any carelessness on their part from causing accident.

These appliances we find in Passfield's Steam Break and Omerod's Self-detaching Hook, and in Williamson's Automatic Break. Detaching hooks are excellent things provided they are kept in good working order; but they should be carefully examined from time to time, and the arrangement for gripping the guide-ropes, where such exists, should be most carefully tested practically, since, though the hook may save over-winding, still there is some remote chance of the break not gripping the guides sufficiently quick to prevent the cage in its descent gaining such increased acceleration in speed as to render all attempts to stop it useless.

The accidents which occur through explosion of fire-damp cannot be considered in detail here. The reader will see, if he happens to be a mining engineer, that the presence of gas in mines can only be tole-

rated in two forms: (1) either it must be undiluted, and therefore unexplosive, or (2) it must be diluted, to meet the requirements of the Mines Regulation Act. To attempt to stop its exuding from the seam would merely be a waste of time and money. Proper and adequate ventilation will do all that is required. With regard to the respective claims and merits of the different forms of safety-lamps we have, we hope, given the reader sufficient information to convert him from the popular notion that the absolute use of a locked Davy (or other form of safety-lamp) guarantees complete immunity from explosion in coal mines. The safety-lamp (as constructed at present) is a safer form of light than a naked light, and, as an invention, is open to great and much needed improvement. A glance at the tables of the properties of the various safety-lamps given in Chapter VII. will suffice to show what we have got and what we require in the construction and properties of safety-lamps.

Although there is not a fault to find with Bidder's electro-magnetic lock we still maintain that all locking of safety-lamps is mere nonsense, so long as any person who knows how can light his pipe at a locked safety-lamp. What we want is some arrangement of the gauze cylinder to prevent this being done. The locking arrangement on Clanny's safety-lamp is little better than a hook-and-eye. De la Baslie's patent toughened glass for the glasses of

Clanny's lamps is not safe. I have known it break when left on a table through no visible cause, unless a failure in the molecular structure of the glass caused dissolution of its composite particles. In Mueseler's lamp we have a really good safety-lamp; and though it is the invention of a foreigner, still colliery owners should consider the value of the invention as a matter of greater importance than the nationality of the inventor. It is to be regretted that the exhibition of apparatus to save life held at Brussels in 1874 was not held in England, as greater opportunities present themselves here for trying inventions in mines.

When considering the question of the frequent occurrence of accident in mines it might not be amiss to discuss the question whether it would not be advisable to compel hewers and all underground men to insure their lives. Of course the colliery proprietor, as the employer, would not do it; the only way would be to stop the miners' wages to the extent of one penny per diem. This would insure them for a sum of 500*l.* at death, or 3*l.* per week disablement. Of course the miners would make an outcry against being stopped even one penny per day, but the simple remedy for that is to refuse to take any miner, if on being engaged, he fail to produce a certificate of insurance. A little determination on the part of the employers would very soon stop any attempt at refusal. Miners are not as a class inclined to save

money out of their wages, and it seems strange that they will pay even 8*s.* a week to their Union, from which they get but little benefit, and very often are urged to strike by the agitators whom they choose to call 'delegates' for no reason whatever. It was never worth any working-man's while to be so interested in the wages of others as the professional agitators are, unless there were some pickings to be got by it; and when these agitators urge the men to strike by extolling the great deeds of the Union, in plain English they are simply exciting the men and urging them to pursue a course ending in starvation and misery. The end of high wages and short hours will eventually be found to land us in a conscription for the army and a lasting depression of trade. Competition with foreign countries cannot be carried on so long as the present arrangements exist between master and man. How can any confidence exist under the present system of short hours, strikes, disputes, rattening, and the abominable trade outrages perpetrated by some members of that highly respectable society, the Trades Union?

It seems hard that whilst miners are earning good wages no precautions should be taken against accident or loss of life. On the London and North-Western Railway every railway servant in that employ has to contribute a certain portion of his wages weekly to an insurance fund. Many find fault with the system, but the majority of the company's ser-

vants are, and have good reason to be, grateful to the directors for establishing this compulsory system of insurance amongst their servants.

The annual number of accidents in mines might be greatly diminished by further precautions. Mining engineers are apt to disregard the difference between precaution and proper precaution. To use safety-lamps is a precaution, but the system of making stall-men find their own powder for blasting is not taking proper precaution, since it tends to encourage the forbidden practice of *unramming missed shots*; it should, therefore, be discontinued. No one for an instant would willingly accuse mining authorities of direct carelessness of the lives of their men, but we think that sometimes too much attention is paid to the output of coal, and the safety of those employed is perhaps for a moment accidentally overlooked, and it is just at these moments that accidents occur. There exists a very great objection to the introduction of new appliances amongst miners. A new form of barometer is looked upon with suspicion. Perhaps the manager is heard to say he would have to alter the ventilating arrangements to try it. Forthwith a rumour goes amongst the miners that a reduction is going to be made in wages, or some such absurd story. Until the prejudice is overcome any marked improvement in the system of working collieries cannot be expected.

To conclude, it is a subject which to state in

detail would be but to go over the beaten track—to reconsider the coroners' inquests. The evidence given in the annual report of Her Majesty's Inspectors of Mines will afford all the information in detail, and a rapid glance will suffice to show those who are interested in it that the matter is not overrated here, and that many valuable lives are lost that might have been saved. Few will deny the statement that saving life is a work that all should assist in. Sir Humphry Davy, George Stephenson, and others began the attempt to save the lives of those employed in mines, and it is to be hoped that with such an end in view those who have succeeded them will not turn back.

In the subsequent chapter some few matters have been carefully considered in detail, with plans and tables. In introducing the subject of spontaneous combustion in ships we have sought in considering it thus to clear up satisfactorily the question of gob-fires. Although not of very frequent occurrence, nevertheless they rarely occur without great risk to those employed in the mine, and, as at Lilleshall, with sometimes fatal results.

CHAPTER XIV.

VENTILATION OF MINES.

In making comparison of the death-rate it is desirable to take the average of time. Mr. Evans, one of Her Majesty's Inspectors of Mines, says in his report for the year 1875 that during the 20 years ended December 1875 the percentage of deaths was 1 death for 127,740 tons of coal raised, and in 1875 1 for 108,918 tons.

The following table shows a comparison for the year 1868 to 1875, and at the end of the book will be found a table of mining accidents for 1876:—

Date	Tons of coal raised In Great Britain	Tons of coal raised In Midland District	Deaths In Great Britain	Deaths In Midland District	Tons raised per death in Great Britain
1868	104,566,959	7,699,265	1,011	60	103.429
1869	108,003,482	8.100.000	1,116	78	96,777
1870	112,875,525	8,366,000	991	50	113,900
1871	117,439.251	9,252,900	1,075	93	109,246
1872	123,393,853	10,657,100	1,060	79	116,409
1873	128,544,400	11,533,307	1,069	78	129,843
1874	126,214.368	12,232,296	1,056	55	119.521
1875	133,306,485	12,430,600	1,224	65	108,918

In 1875 the persons employed per life lost were 430, out of an entire mining population of 535,845 persons employed.

In Mr. Evans' report on safety-lamps and blasting powder we find the following:—'That, in his opinion, the late deplorable explosions of gas have resulted, not from the use of powder, but from the fact that an adequate quantity of ventilation was

not constantly produced.' This statement is more a legal one than a logical one, for no doubt, although the presence of gas in mines is the real cause of explosion, nevertheless it cannot explode of its own accord, and shot-firing does ignite the gas. Of course explosion from shot-firing is a chargeable offence under the particular clause in the Mines Regulation Act which relates to 'adequate ventilation,' but in the opinion of many men the majority of explosions are caused by ignition of gas dislodged sometimes by the shot itself. In our own opinion shot-firing with powder is the cause of half the accidents, and until electrical blasting and gun-cotton are used the accidents will continue to occur.

Mr. Wales (Welsh district), in his report for the year 1876, states that the output in his district amounted to 12,002,412 tons of mineral, causing the loss of 117 lives; in 1875 the output was 10,274,645 tons, with a death total of 127 lives; thus the reduction in 1876 in the mortality was nearly 14 per cent. In the year 1864 the output for this district was 6,948,000 tons, with a loss of 105 lives. The loss of lives in 1876 compared with 1864 is, therefore, equal to a reduction in favour of the year 1876 of 42 per cent. The total loss of life in 1876 was 933 persons. If the rate of mortality which prevailed in 1864 were to have continued up to the year 1876, then the death rate would have been in 1876 1,350 lives lost instead of 933 lives, showing a reduc-

tion of 31 per cent. per annum. Thus we see that the passing of the Mines Regulation Act has been attended with favourable results, and although we have raised more coal we have not lost so many lives in the operation.

In order to enable our readers to form some idea of what is necessary in the ventilation of a mine, the following will be found possibly of some assistance:—A mine consists of two shafts, connected by a complete system of underground airways. There are two methods of imparting motion to the air-current: one is by lighting a large fire at the foot of the 'upcast' shaft, and so, by having hot air in the upcast and cold air in the downcast shaft, securing a draught through the airways. The other method is perhaps the more likely to remain in use, and consists of a fan revolving rapidly at the top of the upcast shaft in a chamber, and so drawing the air out of the pit. By the latter method much of the nuisance arising from furnace ventilation is removed and the pit kept cool.

There are two very important points to be observed when considering the subject of ventilation. The first is *the friction of the air against the sides of the airways, and the diminished velocity of the air-current* in consequence of the friction. No men have thrown more light on this subject than André and Atkinson. We can best arrive at the measurement of the friction in an airway by estimating the

amount of force requisite to overcome it. By experiment it has been proved that where the area or rubbing surface of the airway is doubled or trebled, so also is the friction doubled or trebled; or when the velocity of the air and the perimeter, or rather the sectional area of the airway remain the same, the pressure necessary to overcome the friction is proportional to the area of the rubbing surface exposed to the current. We can find the rubbing surface by multiplying the perimeter of the airway by its length. Thus, in an airway 5 feet square the perimeter of the section is four times 5 feet, or 20 feet; and if 1,200 feet long, then $4 \times 5 \times 1{,}200$ will be the rubbing square, or $20 \times 1{,}200$, or 24,000 feet.

If we double the size of the airway and make it 10 feet square, the perimeter is 10×4, or 40 feet; and if 1,200 feet long, then $10 \times 4 \times 1{,}200$ rubbing surface, or 48,000 feet. Therefore, for four times the area there is only twice the rubbing surface.

If there were two airways, one just twice the area of the other, the velocity of the air and the area of the rubbing surface being equal, then just twice the pressure required by the large one must be applied to each square foot of the smaller airway to overcome the friction. The truth of the above has been very carefully considered and expounded by the late J. Atkinson in his work on ventilation, and a glance at that treatise will suffice to show the reader what is required and how it may be accomplished.

Taking the average of eleven different collieries in the Newcastle-on-Tyne district, each pound of coal consumed in the furnace puts in circulation 13,00C feet of air.

The question as to which is best for ventilation, a fan or an upcast furnacc, admits of no general answer. It entirely depends on the depth of the pit and the general disposition of the workings of the mine. If the coal dips, the upcast shaft should be situated as near the dip as possible; by this means a longer chimney, and consequently a brisker draught, is secured, for an upcast shaft is nothing more than a tall chimney. For shallow pits there can be no question that vacuum fans are better than furnaces. The stoppage for repairs or renewal of machinery connected with the fan is sometimes a serious matter.

When the proper amount of air has been allotted to a given split from the main air-current, it has to be directed properly through the workings. If it was allowed to go where it liked it would go straight to the upcast by the shortest route, and perhaps one-third of the workings would never get any air. To prevent this, therefore, a particular line of march for the air-current to take is decided on, and the side-ways are blocked up by what are technically called 'stoppings.' They may be briefly though not accurately described as brick walls. These stoppings play a very important part in the subsequent safety of the mine after an explosion. We frequently read

in the papers that in consequence of the stoppings being blown out, great difficulty was experienced in restoring ventilation. All stoppings, therefore, that are of any importance should be carefully and substantially erected, and the effect of an explosion of gas always kept in view. Two curved walls, with their convex sides outwards and filled in with sand, constitute the strongest possible stopping.

If the way where the stopping occurs has to be used as a travelling-road, then the necessary stoppings in that particular way must be made like a door of sound oak. In important airways hanging doors should also be erected; these are so constructed as to go about on an horizontal axis, fixed in the roof. Supposing an explosion to take place, the blast of which blows away all the ordinary doors, then the fastening catch of the safety door will be instantly liberated by the rush of air, and allow the door to drop or close as the case may be. By this means ventilation can be rapidly restored before further damage is done.

One of the ventilating arrangements that probably has been more conducive to explosion than any possibly in use, is the practice, now happily becoming obsolete, of allowing the ventilating current to pass through the *broken mine*, as it is called, which is the miner's name for workings not at the working face; this system allowed the air to visit each place in succession, and of course the last

place visited by the current had the unpleasant drawback of the gas, heat, and powder-smoke collected from the other places. If a blower of gas existed in one of the ways the fire-damp was immediately conveyed by the ventilating current to the lights of the men working in the face. The rule to be observed is, never allow the air to pass through broken workings to the face, and so to distribute your stoppings and doors, that in the event of an explosion the air will not be 'short-circuited,' and so change the distribution of the ventilating current.

When discharging the air from the mine into the upcast shaft, it should be (if necessary) discharged through a 'dumb' drift, at a point above the flame of the furnace.

In considering the question of ventilation and the necessary precautions, it may not be out of place to consider the case of coal-dust and its probable effect on explosions spreading. It has been asserted by some that the flame of a shot will fire the coal-dust always floating in the air of the mine, and so contribute to the spread of an explosion; others have flatly contradicted this statement, and denounced it as absurd and impossible; others even appear to think that minute atoms of carbon are sometimes the cause of an apparent explosion of fire-damp, and not the gas. The latter theory is extremely doubtful, though possibly nitrous gas with carbon in fine suspension may be susceptible to explosion.

There is very great difficulty in clearing up this matter; but since it is obvious that the dust must have a pernicious effect on the health of the miners and horses, much will be gained by watering the gate-roads occasionally, and so preventing the dust rising in too large quantities. It is certain that dust suspended in carburetted hydrogen will intensify an explosion by widening its effects.

CHAPTER XV.

UNDERGROUND FIRES AND COAL CARGOES.

In Chapter VIII. we dwelt shortly on the danger incurred by gob-fires in mines. The Royal Commission on Spontaneous Combustion of Coal in Ships has at length issued their report, and there is much valuable information on the subject with reference to vessels that might be well applied in mines. In the first place, the particular conditions necessary to excite spontaneous combustion in coal should be carefully noted, and then the method of dealing with it when the fire has set in. In Chapter VIII. we mentioned one method. There are three primary causes of underground fires breaking out in mines. The first we may call a mechanical cause, and the other two chemical causes.

The mechanical causes are entirely due to carelessness and negligence, and can be easily prevented by a proper amount of discipline being enforced. Candles stuck in the sides of air-doors; non-fireproof brattice cloth; ignition of the coal by the sparks from the underground hauling engine—all these are causes of underground fire, and can be provided against. We next come to the chemical causes. A blower of gas issuing from the roof is accidentally ignited and backs into the seam, and so escapes being properly extinguished, and ultimately sets fire to the actual coal seam.

Spontaneous combustion is another cause. To insure this chemical action taking place certain conditions must be previously existing in the coal. When a seam is called 'brassy' by the miners—that is, when an unusual amount of iron pyrites exists in it—it is in a condition to become ignited spontaneously in the following manner.

The composition of iron pyrites is as follows: FES_2 is its chemical formula; it contains one atom of iron and two atoms of sulphur. If exposed to a damp atmosphere it decomposes; this decomposition is of course attended with a proportionate liberation of heat, and if the heat cannot become absorbed the ignition of the sulphur takes place.

It was at one time supposed that the presence of iron pyrites in the coal seam was actually necessary for the generation of spontaneous combustion; such,

however, is not the case; the only real essential conditions appear to be the following, viz., conditions such as shall secure that the heat generated by the chemical action taking place in the coal shall not escape as fast as it becomes generated; that the coal shall be broken up into small pieces, and so expose a large surface to the air. When these conditions are complied with and the coal exposed to a moist atmosphere, oxidation takes place, by which chemical process a large amount of heat is generated, and so the coal becomes fired.

Now, having considered the causes that lead to this generation of heat, we are in a position to determine what are the best and most practicable methods of preventing the causes, which are resolved into a *moist atmosphere* and the *presence of small coal* in that atmosphere. One method is to remove all small coal and draw it to the surface. This is not always practicable, on account of cost. If the seam contain pyrites it had better be done at any expense; if not, the next method may be tried, which is to exclude the air from the heaps of small coal in the workings by putting in stoppings, as referred to in Chapter VIII., and erecting barriers; but here we meet with another difficulty, which is, to insure that the district shall be wholly cut off from the air, and, so to speak, hermetically sealed.

The first two methods prevent chemical action setting in, and are precautions that should be taken

before a gob-fire sets in. The next method is applicable both to the extinction at an early period and the prevention of underground fires.

The latter method consists in directing a strong current of cooling air on the surface of the small coal. This is only applicable when heat has been generated and actual ignition has not taken place, for by the cooling influence of the ventilating current any dangerous accumulation of heat is prevented. It is a peculiar feature worthy of notice that gob-fire rarely occurs where the roof is sandstone, but when shale strata lie next the seam and form the roof, gob-fire is of frequent occurrence. This may be explained as follows:—The sandstone, being more or less porous, allows the free escape of heat and gases upwards, and the shale acts in a reverse manner by confining the heat. By blowing in the roof, although a bold measure, the escape of the heat may be insured where the shale strata are not of any great thickness.

Gob-fire more frequently occurs in deep workings, and the chance of its setting in decreases as the workings approach the outcrop or ending of the seam towards the surface. We may recommend the following to our readers as rules to be observed when gob-fire has actually set in or an underground fire has broken out:—Apply water at once, to prevent its gaining a firm hold on the coal. Isolate the workings where the fire exists by erecting barriers. See that the workmen who are employed in erecting

barriers have respirators, water, oil, and lint, in case of burns or explosion.

Allow no time to elapse in useless discussion as to what is to be done, but decide at once what you intend to do, and tell off the necessary staff to do it. Place brick, clay, sand, mortar, and tools at a suitable distance 'out bye,' so that in the event of being driven back by the fire, you can make your escape and put in a stopping at once. When the burning district has been got under, extinguish with either carbonic acid gas or steam, in either case taking care to prevent a back draught blowing your remedy back on the men.

Never flood the mine unless you have either got the fire in the dip or cannot put it out, as the cost of pumping out and the damage done to the workings are very serious items. For a description of treating gob fire we refer our readers to a Paper read by Mr. George Thompson before the Iron and Steel Institute on the extinction of a fire at Wynnstay Colliery, Ruabon, by carbonic acid gas, in 1874. This method was successful, and the fire was extinguished at a moderately small cost. Here we meet with another difficulty, as, although successful in this case, carbonic acid gas generated by the action of hydrochloric acid on limestone or chalk does not exert any particularly cooling influence on a mass of ignited coal; in fact, it is only applicable where atmospheric air can be effectually stopped off.

Water and steam are the only agents that are practically available in most cases of gob-fire.

A perusal of the following tables will give the reader some idea of the importance of the subject as far as regards the shipping interest of this country alone.

The coal annually exported from the United Kingdom is chiefly shipped from the Tyne, the Wear, the Mersey, and the Bristol Channel. The Scotch and Yorkshire ports also export a considerable amount. For the years 1873, 1874, and 1875 the following tables give the comparative export of coal from these chief coal-shipping ports. The export of coal from this current, it will be noticed, is very steadily increasing, for in 1873 twelve million tons of coal were exported, and in 1874 nearly thirteen and a half million tons were shipped from the United Kingdom; and notwithstanding this large increase in the first two years, we find in the year 1875 the export to have increased still further by half a million to nearly fourteen million tons. The comparative shipments are shown as under:—

Ports of Sailing	1873	1874	1875
	Tons	Tons	Tons
From the Tyne . .	Over 3 millions	Over 3 millions	Over 3½ millions
,, Wear . .	Under 1½ ,,	Under 1½ ,,	Nearly 1½ ,,
,, Bristol Channel	Over 3½ ,,	Nearly 4 ,,	Nearly 3¾ ,,
,, Mersey . .	Over ½ ,,	Nearly ¾ ,,	Under ¾ ,,
,, Scotch ports .	Over 1 ,,	Over 1½ ,,	Over 2 ,,
,, Yorkshire .	Over ½ ,,	Over ¾ ,,	Over ¾ ,,

From the return prepared by Lloyd's it seems that in 1874 there were 31,116 shipments of coal,

representing a total of 13,369,012 tons. The casualties were 70, but of these shipments 26,638, amounting to 10,513,181 tons of coal, were to European ports, including the ports in the Mediterranean and the Black Sea, and only suffered from spontaneous combustion in ten cases. It will be noticed, therefore, that from this return we have to account for 60 casualties (after deducting both casualties and shipments for European ports), and have 4,485 shipments, representing 2,855,831 tons of coal, to Asia, Africa, and America; or it may be summarised as follows:—

To European ports . . .	10,513,181 tons shipped,	with	10 casualties.
„ Asia, Africa, and America	2,855,831 „ „	„	60 „

A very remarkable feature of the case is that the proportion of casualties increases *pari passu* with the tonnage of the vessel carrying the coal. The following table, after deducting the European trade, illustrates this for the year 1874:—

Shipments	Quantities Conveyed	Accidents	Percentage of Accidents
2,109	With cargoes under 500 tons .	5	Under $\frac{1}{4}$
1,501	„ „ between 500 and 1,000 .	17	Over 1
490	„ „ „ 1,000 and 1,500 .	17	$3\frac{1}{2}$
308	„ „ „ 1,500 and 2,000 .	14	$4\frac{1}{2}$
77	„ „ over 2,000 . . .	7	9

The casualties in vessels bound to San Francisco are very remarkable. Deducting in this case vessels under 500 tons, in which no cases of fire occurred, the return shows nine casualties out of fifty-four shipments. These increase in proportion to the ton-

nage, till we arrive at the alarming fact that out of the five ships with cargoes of over 2,000 tons sent to San Francisco two were burnt by spontaneous combustion. Of such shipments to Asiatic ports beyond the Mediterranean over 4 per cent. suffered in 1874; and though they only amounted to 1,181 out of the 31,116 shipments for the year, fifty-one out of the seventy casualties occurred among them!

These tables, though they do not refer to mines, nevertheless show that what is applicable to ships is also applicable to mines. Heat, damp, iron pyrites, sulphur, ventilation through the coal instead of over the surface of it—all these are direct causes of spontaneous combustion and gob-fire, and should, therefore, be rigidly guarded against.

Having had occasion to fight a gob-fire in a mine, I may mention that in using gunpowder in a pyritic seam *small-grain powder* had better be used, and not *gun-cotton*, on account of the quantity of heat evolved on combustion; by using large-grain powder there is some risk of incomplete combustion and the firing of the coal.

Captain Cawkitt, the manager of the Liverpool Salvage Association, in his evidence given before the Royal Commission on Spontaneous Combustion in Coal in Ships (in 1876), said that 'most of the burnings in the ships we have heard of have been *under the main hatch*, and the bulk of the burnings have been in vessels that have been loaded under the tips where the coal is broken, and where there has been

a lot of small coal accumulating round the main hatchway, and I believe in most instances the fire has been proved to have originated about the main hatchway.'

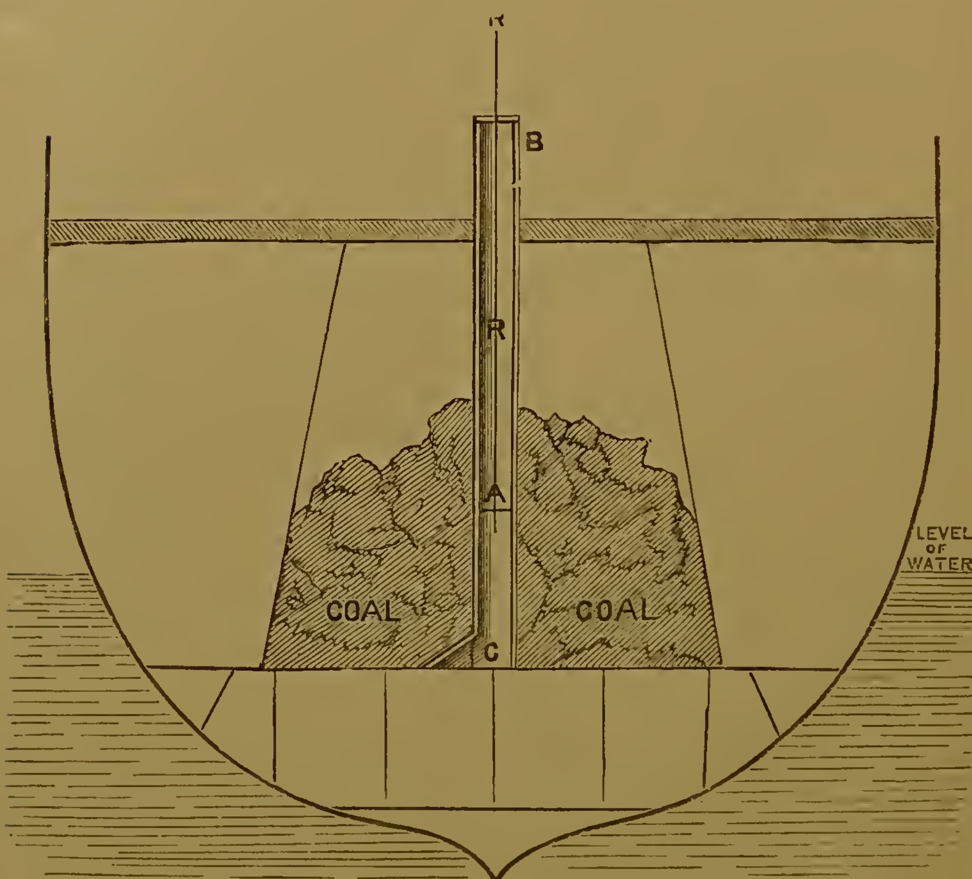
This evidence is very valuable, and was borne out by many witnesses; and the danger of the existence of small coal near the main hatchway appears to be well recognised in some districts, since we find Mr. Cooper Rundell, who is accountant to the Liverpool Underwriters' Association, quoting from 'Stevens on Stowage,' stating that in South Wales it is the practice to dig out a small quantity of coal from the hatchway after the vessel has completed her loading and to replace it by larger coal. The 'tip' or 'spout' system of loading vessels with coal tends to breakage of the coal, and is the cheapest and the quickest; but the 'box' system, or loading by barrows, does not; but against this we must consider that the latter form of loading is slow, and consequently more expensive. With the former method about 1,800 tons can be put on board in forty-eight hours, whereas by the latter only about 250 tons per day can be stowed.

From the statistics of Mr. Cooper Rundell it appears that of the shipments from the port of Liverpool with 500 tons of coal and upwards on voyages across the Equator or through the Suez Canal, in the years 1873, 1874, and 1875, 348 vessels were loaded by tips and 608 by hand. Among the

former the casualties were twenty-one, while only four casualties occurred amongst the latter. The sum-total of this evidence shows that however a vessel is loaded the points to guard against are—fine coal, moisture, and a current of air *through* the coal.

The following method would, we believe, be found worthy of consideration :—

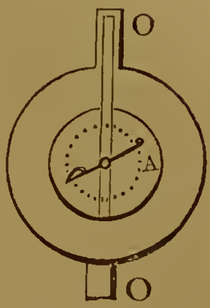
Fig. 1.



The above represents the section of a vessel. B C is a wrought-iron pipe 6 inches in diameter, shaped

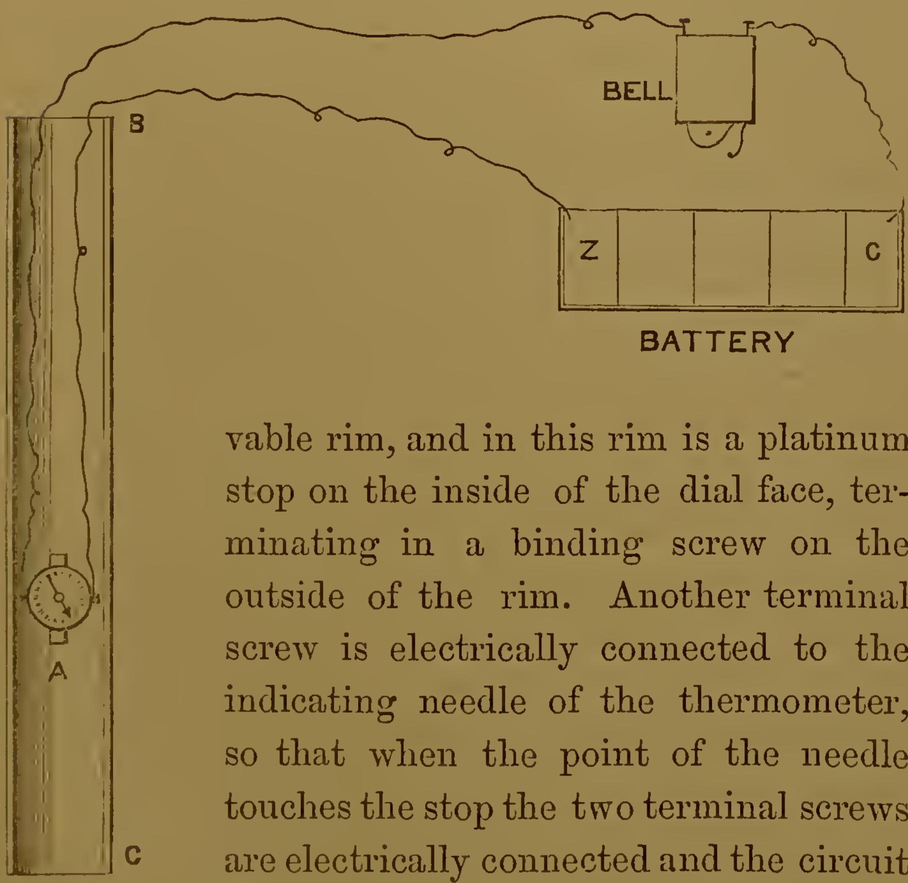
circularly in section, and perforated; O O, in fig. 2, being two grooves cut to receive a projecting stud on each side of one of the patent thermometers, A.

FIG. 2.



The pipe B C should be closed with a cap, and the thermometer attached, with a chain, R, and thus made capable of being lowered or raised up and down the pipe B C at pleasure. The thermometer is provided with a mo-

FIG. 3.



vable rim, and in this rim is a platinum stop on the inside of the dial face, terminating in a binding screw on the outside of the rim. Another terminal screw is electrically connected to the indicating needle of the thermometer, so that when the point of the needle touches the stop the two terminal screws are electrically connected and the circuit is *through*; when the needle does not touch the stop

the circuit is broken. The thermometers being metallic, no amount of vibration or change of position will injure them. The electric wires are brought up the tube and connected there (fig. 3) with an alarum placed in the captain's cabin, engine-room, or wherever else is thought advisable, a bell being placed in circuit at any place where it is thought necessary. The thermometer should be raised and the temperature noted frequently; the stop should be set at 100°. Should the heat suddenly cause the coal to rise to that temperature the needle will advance, and, touching the stop, make contact and continue to ring all the bells at the different stations in the ship until the temperature falls. The pipe forms a ready method of admitting steam or water to the heart of the cargo, neither of which agents will injure the internal mechanism of the thermometer, which will stand a temperature of 300° Fahrenheit, or more if required.

A pipe of this description could be placed in each compartment of the ship. I consider that nine thermometers, pipes, wires, and battery complete, might be fitted at 120*l.* outlay for a ship of 1,500 tons cargo; or, roughly speaking, an outlay of 120*l.* would reduce the risk of loss of more than 800*l.* of cargo alone; against which figures must be set off the reduction in premiums of insurance, as we conclude that insurance companies would hardly consider a ship thus fitted to be no safer than one in which no precautions had been taken.

A serious objection to the use of carbonic acid gas for the extinction of the fire in the hold of a ship is, that should it be found necessary to enter the hold without respirators it would be impracticable.

The same arrangement of thermometers has been most successfully applied at Brora Colliery, where gob-fire is frequently occurring; in fact, we may quote a letter from Mr. Edwards, the manager of the colliery, to whose skill in treating the question the existence of Brora Colliery is mainly due. Writing of this apparatus, he says: 'There is no doubt whatever but that it will indicate spontaneous combustion *anywhere*, if it is placed in a position to do so, since, if the temperature rises, it will ring the alarm-bell when it gets to the place indicated on the dial. If the gob should heat spontaneously it will ring the bell in my office, so there is not the slightest doubt but that it will do its work.'

This apparatus has been frequently brought under the notice of shippers, but the inevitable reply is, 'We are insured;' and here lies the whole truth of the loss of life and property in working and carrying coal. The danger is such, and the cost of appliances to obviate it so great, that it will not pay to use them unless the coal will fetch a higher price. What do the public care about the loss of seventy lives more or less compared to the price of the coal remaining unaltered? The sym-

pathy of the public was roused during the recent colliery inundation at Pontypridd, when the Welsh miners proved themselves to be no cowards, as miners have often done before; but we venture to say that the indignation of the very subscribers themselves to the Mansion House Fund for the relief of the men would be tenfold greater than their sympathy were coal to rise two shillings per ton.

The loss of lives must always bear a direct proportion to the price the coal fetches, as well as to the number of tons raised; in fact, the case is like that of buying a gun or boiler. You may buy a cheap gun, and it will probably burst. If we save our money owing to the low price of coal, we shall lose our men.

It is worthy of notice that the presence of sulphur does not always cause gob-fire in coal. In Tasmania there is a vein of resiniferous shale that contains as much as 5 per cent. of sulphur in combination with carbon and hydrogen. Sulphate of lime is sometimes present in coal, but this is a combination the sulphur of which is already oxidised, or, so to speak, slowly consumed, and therefore harmless.

At the end of this book a comparative table of coal shipments and casualties is subjoined.

CHAPTER XVI.

INUNDATION OF WORKINGS BY INFLOW OF WATER.

There are various methods for preventing the surface water, which is always draining through into a mine, from collecting in too large a quantity.

The sedimentary rocks contain permeable and impermeable beds. Sedimentary rock is deposited in small particles, kept together by pressure, and it will be at once seen that if the pressure and other local conditions which insure the cohesion of the particles of the rock are removed, the rock becomes more or less porous, and capable of holding water like a sponge.

An important fact is very plainly illustrated by André in his work on 'Mining Engineering.' He says: 'Suppose rain to fall on a patch of permeable rock underlaid by an impervious stratum. In this case the excess will flow off by the stream; the remainder, over and above that absorbed by plants and removed by evaporation, will pass down till it meets the underlying impervious stratum, and then flow out in all directions round the edges of the permeable bed. It is to be observed that if the lower and impervious beds were inclined the water would flow out of the upper and permeable bed to-

wards the dip and strike only, and not towards the rise, and the flow will be greater towards the dip.'

In estimating the probable quantity of water to be met with the above should be carefully borne in mind.

Faults in the seam are a common source of water in mines, and sometimes contain a very large amount. The fissures and cracks along the rim of the fault may sometimes allow the water to flow off; but again, on the other hand, they may serve as feeders, and the fault then becomes a reservoir on a small scale.

It should be always ascertained by an above-ground survey and measurements whether a large portion of roof falling in the mine will allow the water in ponds, etc., on the surface to come through into the mine. To judge of this question we must first consider what strata lie between the surface and the roof of the mine, and whether they are impervious to water or not. We must also ascertain whether they are inclined or horizontal strata.

The disruption and fracture of some beds by being 'let down' vary considerably with the nature and composition of the bed; for instance, a bed of clay, or slipper, which are both yielding and plastic, if let down would not break up, but simply sink into a concave form; but limestone or sandstone, under similar circumstances, would break up, and long fissures and cracks would run through the dis-

trict near the subsidence, through which the surface water would pass until it reached the mine.

Large caverns may often be noticed in the face of a chalk-pit or limestone quarry. They may be very plainly seen in the chalk-pit at Odiham, in Hampshire. It would seem that they are formed either by water having a strong acid reaction being deposited there, or by the acid reaction of carbonic acid gas on the calcium, as water in limestone strata may frequently be found charged to excess with this gas, which on any decrease of pressure on the water bubbles to the top. These caverns very frequently contain water, and their existence cannot be foreseen in mining.

It is much to be desired that some more active steps were taken to rid the ten-yard-thick coal in the Dudley district of water. A Mines Drainage Commission was appointed, but we fear will not exist in a year's time, owing to the want of combination of the local pit-owners. In approaching a fault in heading out, a bore-hole should be put through the fault, like tapping a cask, but this should not be done without the erection of a barrier behind, if water be suspected beforehand, and it would be safer at all times to do it; but the expense of the operation when unnecessary must be considered.

The barrier should be brick, curved, in the form of an arch, to withstand the pressure if the inflow is likely to be considerable.

To treat of the question of pumping machinery would be of no use here, as the question has been fully gone into, and belongs more to a work on mechanical engineering. For such information, such as horse-power required, lifts, and all the calculations found necessary for erecting pumps of sufficient capability we refer our readers to André's 'Mining Engineering,' vol. ii., where, under the head of 'Pumping Machinery,' every possible information has been given, illustrated by diagrams and plans.

The late inundation at Pontypridd (1877) has been very clearly explained by means of diagrams in the 'Graphic' newspaper. Here we see the importance of erecting barriers when approaching a fault, especially when the close existence of an inundated and abandoned mine is known beforehand; those precautions were not taken, neither was due care exercised in ascertaining the exact locality of the fault, and in consequence the water broke in and flooded the pit.

A verdict of manslaughter was returned against the manager of the pit; but we think, in common with many others, that although due care was not taken, yet the courage the defendant exhibited during and after the accident might have been looked on from a point of view which, although not legal, may be considered as extenuating circumstances. In this case the colliery maps appear not to have been kept up to the mark, or the fault would have been more accurately 'localised.'

CHAPTER XVII.

THE BUNKER'S HILL COLLIERY EXPLOSION.

Mr. Wynne, in his report for 1875, made a few remarks that are well worthy of notice. The reason we quote his report here is that Blue Books are very rarely read by the public, on account of the mass of evidence they contain. Surely it would be a good plan to abridge some of the more important reports, such as those of Her Majesty's Mines Inspectors, for private reading. Mr. Wynne, in his report for the year, says: 'The sad calamity at Bunker's Hill and the cause of it is so fully stated, and the way to prevent such explosions so clearly pointed out in Mr. Dowdeswell's report and my own, that I cannot do better then insert copies of them, together with a plan of the mine, as produced at the inquest; but before quitting this melancholy subject *it is but just to myself to state that no blame attaches to me for this loss of life by explosions, for I have, year after year, pointed out the "farce" of using locked lamps where the most dangerous of all lights is allowed (blasting), and therefore the awful responsibility of sanctioning a course that leads to such terrible losses of life rests on other heads, and not on mine.*'

It is some satisfaction to know that nothing would induce the proprietors of the Bunker's Hill Colliery

to resume the use of gunpowder; but a very natural question arises, *whether it be advisable to allow these dire calamities to take place, destroying hundreds of valuable lives, which in the opinion of many persons are preventible, by the simple prohibition of the use of explosives in fiery mines*; or, in homely phrase, to 'lock the stable before the steed is stolen'?

The reports of Mr. T. Wynne, Inspector of Coal Mines, and Mr. G. W. Dowdeswell, Q.C., respecting the inquiry into the fatal explosion, on April 30 last, at Bunker's Hill Colliery, by which forty-three lives were lost, have been laid before Parliament.

Mr. Wynne, Her Majesty's Inspector, says: 'I have the honour to transmit to you a full report of what took place at the inquest on the forty-three poor fellows who were killed by the explosion at Bunker's Hill Colliery on the 30th ult. I am much indebted to Mr. Dowdeswell for his able assistance in so clearly bringing out the facts of the case, and I believe he will report to you what, in his opinion, is the only mode of avoiding such calamities.

'For more than twenty years I have been pointing out what a "farce" it is to prohibit the use of naked lights in mines and yet allow powder to be used, and have indulged in the hope that self-preservation would prevail over the more idle method of getting coal by blasting; but I am now satisfied that the only safe course to take is to prohibit the use of all explosives in coal mines, and in a few years

the coal-owners would wonder how they could have allowed their coals to be blown to atoms and the roofs shaken, as they have been for so many years; and the colliers would find that, having got rid of the impure fumes of powder-smoke and the dangers of explosions, together with the comparative safety from falls of roof, they were amply repaid for any extra labour the wedging process entailed.

'Nothing could more clearly show the advantage of wedging, over the use of powder, than the state of the two downbrows of 600 yards each, which effectually withstood the enormous strain which must have been put upon them by the force with which the air was driven from the seat of the explosion to the top of the upcast shaft, for not so much as a hundredweight of coal was blown down in them, or the dips in the slightest degree injured, or, indeed, was that portion of the levels, which was driven without blastings. The only reason assigned for the change from wedging to blasting was, that Mr. Rigby could not compete with his neighbours if he wedged his coal and they blasted theirs; so that, to meet competition, he was obliged to increase production and lessen cost.

'Mr. Hall, Mr. S. B. Gilroy, and myself are of opinion that the explosion was caused by the use of gunpowder; nor, indeed, could there be two opinions on the subject; and we are of opinion that the use of

powder or other explosives, should be entirely discontinued in fiery mines.

'Suggestions have been made that all shots should be fired during the night, but to me it seems a hard case for the firemen to be turned into a "forlorn hope," for the fatal explosion at Ince Hall Colliery last year shows that even that system is not a sufficient precaution for the safety of human life. I think it only proper to instance Bunker's Hill Colliery as a case forcibly illustrating the superiority of the fan over other means of ventilating mines, as the engines, with a slight increase of speed (the fan being uninjured), restored the air-current almost immediately after the explosion, enabling a party of explorers to enter the workings, to refix the stoppings, recover the bodies, and ascertain the extent of the disaster with the least possible delay. You will see that I do not attribute any blame to anyone connected with the management of the colliery, powder being at present in general use in the district, as are also the small air pipes or tubes for the purpose of conducting the air into the extremities of the workings.'

Mr. Dowdeswell in his report says: 'My attention was principally directed to three points: first, to ascertain the cause of the explosion; secondly, to see whether the requirements of the Mines Regulation Act had been strictly observed; thirdly, whether any feasible precautions could be adopted to avoid

such a catastrophe hereafter. Every person who was in the mine at the time of the explosion having perished, the cause of the explosion could only be gleaned from the subsequent examination. The conclusion is irresistible that the explosion was caused by the firing of a shot in the thirling marked X on the plan, on the east side of the engine-brow. I cross-examined the witnesses, in order to ascertain whether the rules had been strictly observed, and I am satisfied there had been no infraction of them. The fireman whose duty it was to fire the shot, and who had evidently fired it, was an experienced, steady man, and some of the witnesses proved that before firing shots he used to take the proper precautions of carefully testing the neighbourhood with his lamp.

'But I elicited from them that the customary mode of igniting the touch-paper of the shot was most dangerous. The fireman, having tested the spot, withdrew to what he considered a place of safety, and there he opened his lamp; some touch-paper was lighted at it, and this was borne alight to the fuze, which was then kindled, and the fireman retired to some spot where the shot could not reach him. In this instance, evidently, the fuze had been kindled, and the man had so retired, and the explosion was caused by the flame of the blast.

'A common notion prevails among the miners that there is no danger of an explosion from a shot if it

fires inwards and does not blow out, but this case shows the idea to be erroneous, a large portion of coal having been dislodged by the shot. The source of the gas which exploded must remain to some extent matter of conjecture; but there had evidently been a disengagement of gas from the flood of the mine, in the immediate neighbourhood of this thirling, and Mr. Gilroy was of opinion that so rapid is its action that it may have been developed and filled this thirling, which is on the rise, in the short interval between the examination of it by the fireman and the firing of the shot, and in his opinion Mr. Wynne seemed to concur. If this be correct, I can suggest no precautions which will be effectual, should blasting be practised; but whether this be the case or no, the lesson this catastrophe teaches is, *that either the use of gunpowder in gaseous mines should be altogether prohibited, or, if its use be allowed, the shots should be fired only between the shifts, when the firemen alone are in the mines.*

'If this course were adopted such a terrible calamity as the present could not occur from this cause. I believe it would also tend to security against explosions from other causes. The firing of the shots produces a severe shock, and tends to the sudden development of gas. If the shots were fired, as they would be, immediately the men left the pits, time would be allowed for this development, which would be detected on the examination just before

the next shift came down, whereas now it may and doubtless is sometimes developed while the men are at work.

'In the course of the inquiry it appeared that *this colliery was ventilated by means of pipes. This is certainly, as the jury thought, a defective mode of ventilation; it seems to be largely on the increase, and it certainly should be discouraged. Unless it be checked I fear a danger of explosion will arise, which a better system by means of brattice would prevent.*'

I have quoted this special case as it illustrates a great deal of what has been discussed in the previous chapter. The system of ventilation by pipes is a very grave mistake, and, until the consequences of employing this system are seen, we cannot expect it to be abandoned, although it is so well shown by the above case to be wrong.

Another habit, which comes under the head of '*shot firing*,' is in use in sinking operations, and how it can be permitted we fail to understand. In sinking shafts it is a common, in fact a general practice, to fire perhaps six shots together.

Having charged and rammed the holes, six equal lengths of fuze are inserted, one into each hole, and the ends of all ignited; the signal to wind up is then given, and the sinkers are wound up in the baulk to the surface, and there await the explosion of the blasts. Now, it is evident to even a person who is

ignorant of the practical part of blasting with gunpowder that because six pieces of fuze are the same length nevertheless they will not burn at the same speed, consequently some of the shots are prematurely ignited; that is, they explode before the others; and here is a direct cause of accident that might be obviated; whereas, on the other hand, if they do happen to burn at the same speed, the shots are fired simultaneously, and it is impossible to tell whether all have exploded, or whether some have hung fire or missed altogether.

The remedy is to use electrical fuzes joined up in single circuit, and to fire from the surface with a firing key apparatus, the key of which should be in the charge of the master sinker or charge-man, or some one responsible person *who is in the pit bottom.* The shots cannot then be fired till he comes to the surface, and on raising the firing key all further chance of ignition or explosion is cut off.

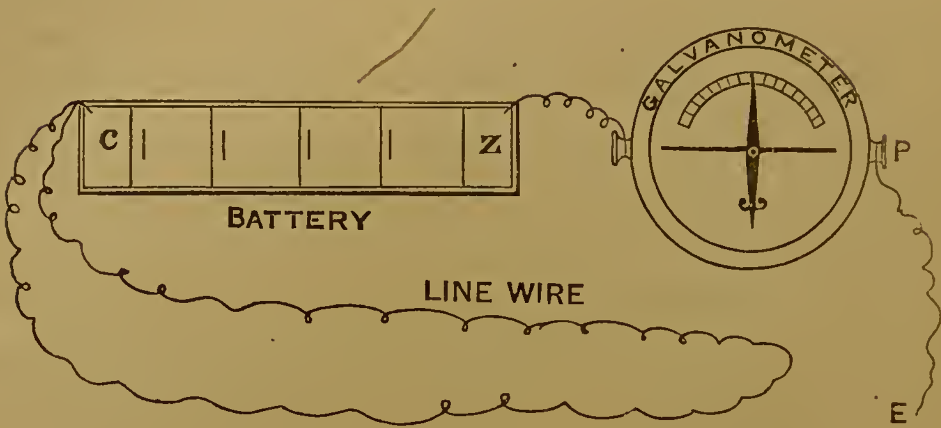
Great care should be exercised in the use of frictional electrical machines for firing fuzes, lest, through imperfect insulation, the machine allows the current to escape to earth. It will be found advisable to insulate the machine from the ground on a sheet of ebonite not less than five-eighths of an inch thick. We have tried all forms of firing machines where electricity is the agent, and we can only recommend Siemens' and Gramme's magneto-electric apparatus,

or a bichromate of potash battery, joined up with one of Apps' patent induction coils. These coils we can speak well of, having had a four-inch one for nine years in use in mines, close headings, drifts, and, in fact, every place where we would naturally have supposed that the insulation would have been defective. We do not recommend Abel's fuzes, as we have in many instances had not only miss-fires with them, but, what is worse, when using gun-cotton, viz., ignition of the charge instead of detonation, and the consequences may be very deleterious to the health of the men at work in the heading.

It is very easy to join up a fuze after firing a set of shots, having omitted to shut off the battery. Mr. Apps has overcome this by mounting on the coil a spring contact-key that cannot be left 'in circuit;' but in all cases we would advise our readers to attach the fuze to the wire before putting the fuze into the charge-hole; by this means, should the circuit be accidentally complete no worse consequence can happen than the mere explosion of the fuze. When using frictional or high tension electricity it must be borne in mind that, like high pressure steam, it will escape 'to earth' wherever a leak occurs in the insulating material which covers the wires. It will be found advisable to make an occasional test of 'earth' connecting as below, when,

if the wires leak, a deflection will be obtained on the galvanometer:—

Fig. 4.



From the above it will be seen that if the lower wires leak to earth a copper current will pass through to the pole marked P of the galvanometer, and, by passing through the coils and then deflecting the needle, regain the battery at the zinc or Z end. If no deflection takes place the insulation of the line is perfect. In putting the pole P of the galvanometer to earth it had better be joined by a naked wire to coal or a water-pipe, both of which are generally available in a mine, and before making the test of insulation as above put the lower wire to earth temporarily, when you should get a deflection; if not, the 'earth' is defective, and must be increased in area.

The most convenient form of battery to use in connection with Apps' patent induction coils is the bichromate of potash bottle battery. Care must be taken to disconnect one battery wire from

the coil, as possibly, through the accidental inclination of the bottle, the zinc plate, although to all appearance withdrawn from the exciting fluid, may yet be partially immersed, and so produce a current.

The best charge for this battery and the chemical action of the elements are as follows:

(1) $H_2\,SO_4 + Zn = Zn\,SO_4 + H_2$

(2) $K_2\,Cr_2\,O_7 + 4H_2 + 3H_2\,SO_4 = K_2\,C_2(SO_4)_3 + 7\,H_2O$

The violet crystals found deposited on the carbon plate are composed of what is commonly called chromium alum, which in reality is potassium chromium sulphate.

The charge is most effective when prepared in the following proportions:—

$\frac{1}{7}$ part of best commercial sulphuric acid.
1 gallon of clean water.
1 lb. of crystals of potassium bichromate.

Mr. George Mowbray mentions, in his experience at the Hoosac Tunnel, the following. In his opinion, the air escaping from the compression through the vulcanite connecting tube produces a considerable amount of ambient electricity, and thus great care should be exercised when using sensitive fuzes.

In fact, we may consider the blaster in the india-rubber boots to be nothing more than an insulated Leyden jar. He inserts fuze after fuze until he comes to the last, when on joining up with the return wire

he discharges himself through the sensitive priming of the fuze. An explosion follows. This feature of frictional electricity should be very carefully considered by those engaged in tunnel work. The remedy is to join the leading and return wire together for an instant, and to grasp a metal rod or pipe with the bare hands, moistened, and so discharge oneself and the wire to earth before joining up the fuze.

The above precaution should always be taken in tunnel-driving, and tests for insulation, as previously described, should be taken constantly, otherwise electrical blasting is as dangerous, and perhaps more so, than with Bickford's time-fuze.

WALKER'S DETACHING HOOK.

Although we infinitely prefer Williamson's automatic break, the following plans will illustrate, perhaps, what may be considered to be the best, or at all events one of the best, of the safety links for the prevention of over-winding. The weight of the hook is, for a three ton load, only 25 lbs.; for a five ton load, 60 lbs.; and for an eight ton load, 150 lbs., the length being from 18 to 30 inches.

Some prejudice has always existed in the minds of mining engineers on account of the very remote possibility of a sudden check on the winding rope or gear when running in the shaft, causing the hook to release the cage. This to our knowledge has never

happened yet, and it appears to us that if safety appliances are not to be used on the ground of what *might* happen if they went out of order, then we are not justified in winding at all, as if anything goes wrong, and the cage is over-wound, there is no question of what *might* happen, as anyone who has seen a case of overwinding can well testify.

In erecting this system of safety links the following precautions should be taken:—The line of the rope should pass down the centre of the ring, and the supporting timber should be as near to the pulley-wheel as possible, care being taken that the capping of the rope shall be able to rise fairly above the top of the ring without being thrown out of line. The timber must be made thoroughly secure, as it will have to resist the upward strain of shearing the pins off, and the outward pressure of the weight of the load in the cage.

In 1875 two cases of over-winding took place when the safety link was in operation, one at Crook Hall Colliery, Durham, and one at Cassop Colliery. In the former case two lives were saved, in the latter one life. 'In both cases the hook acted admirably.' So says Mr. Bell, Her Majesty's Inspector of Mines for that district.

The automatic break and this safety line ought to entirely settle the question of over-winding. An engine-man may very easily raise the up-cage when the engine is still in forward running gear.

We have very frequently seen engine-men asleep in the engine-room at night when nothing is going on and the pit is idle; this should be stopped summarily, as no man is as fit, after having once dozed, to carry out such work. The inclination to drop off

Fig. 5.

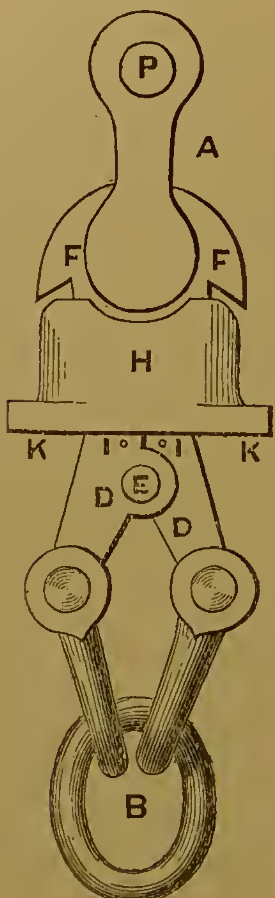
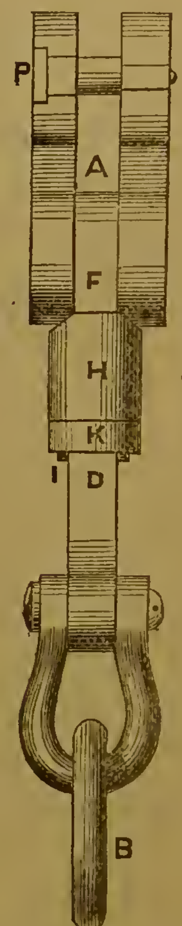


Fig. 6.



to sleep again after having once dozed becomes so strong that it requires a very strong determination to overcome it absolutely.

The figure shows Walker's Detaching Hook in several different positions. Ormerod's hook is some-

what different in construction, though the principle is the same, and there is little to choose between

FIG. 7.

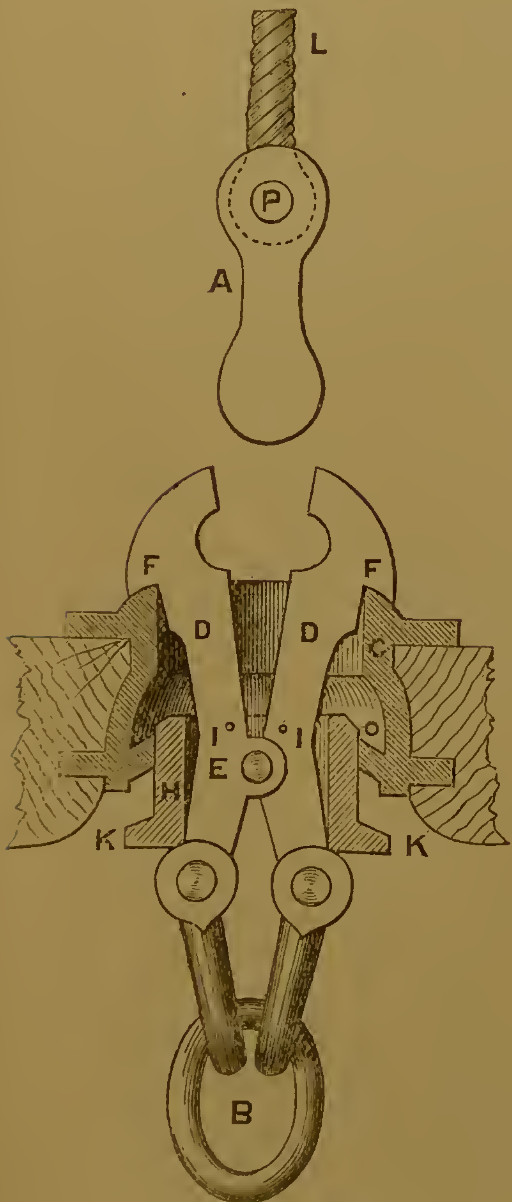
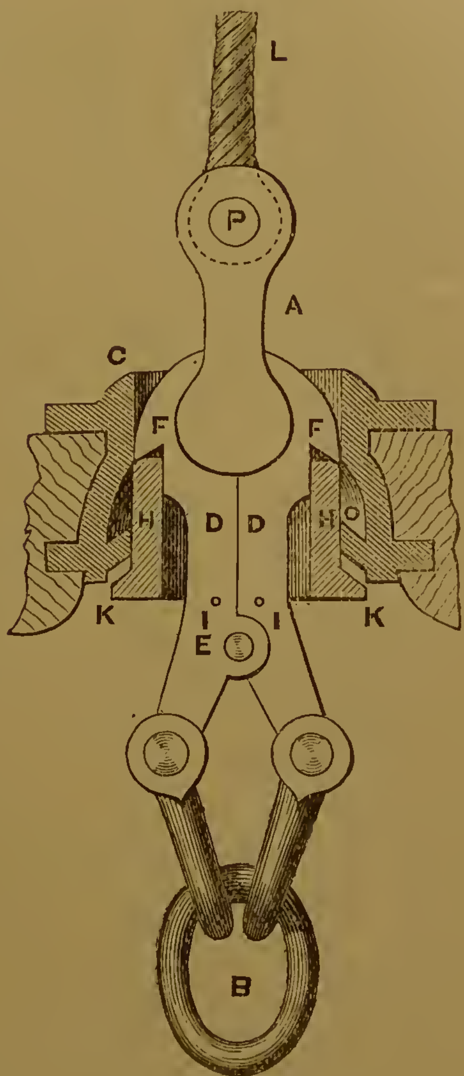


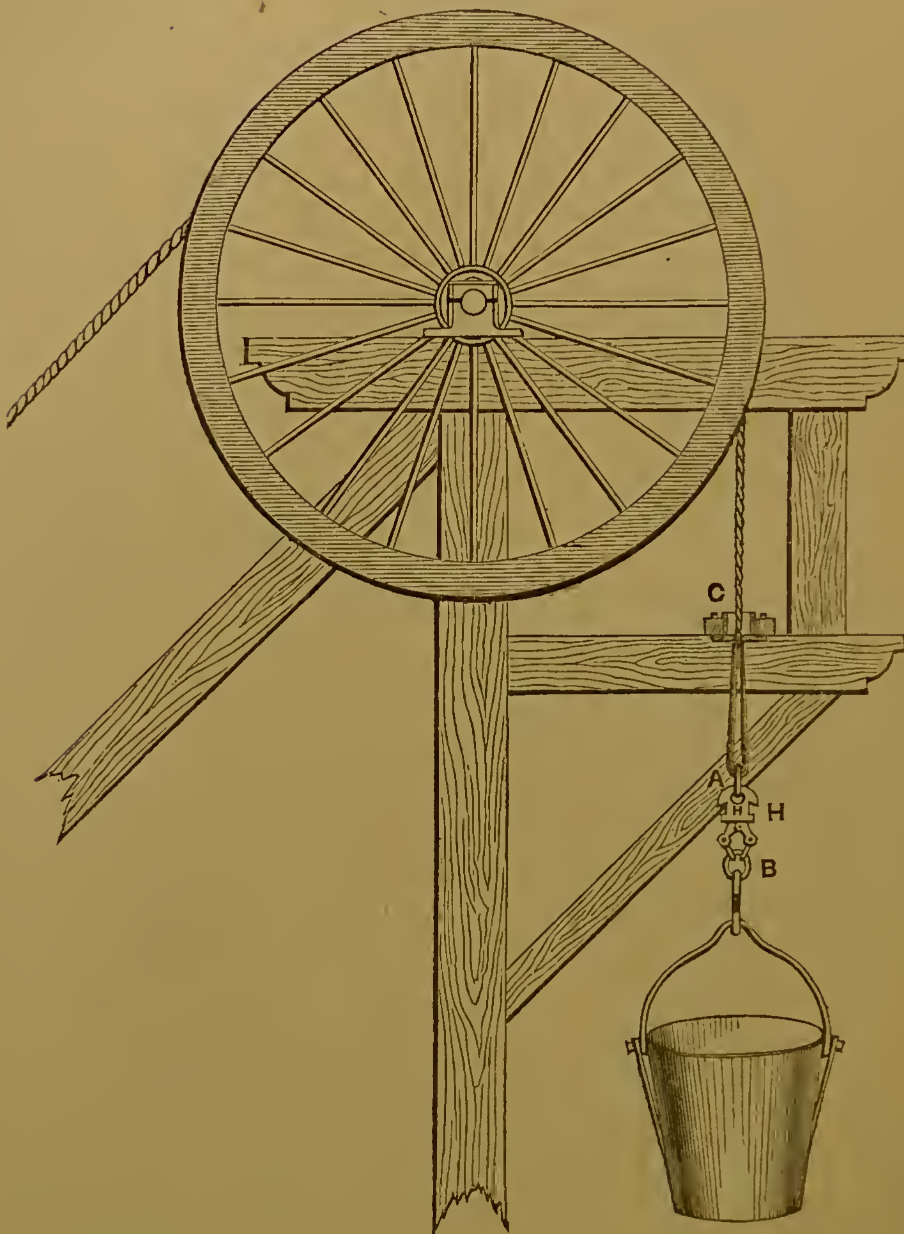
FIG. 8.



them. Another patent has lately come out under the title of King's Patent Detaching Hook, and if the

hook is made as represented by the plan we cannot

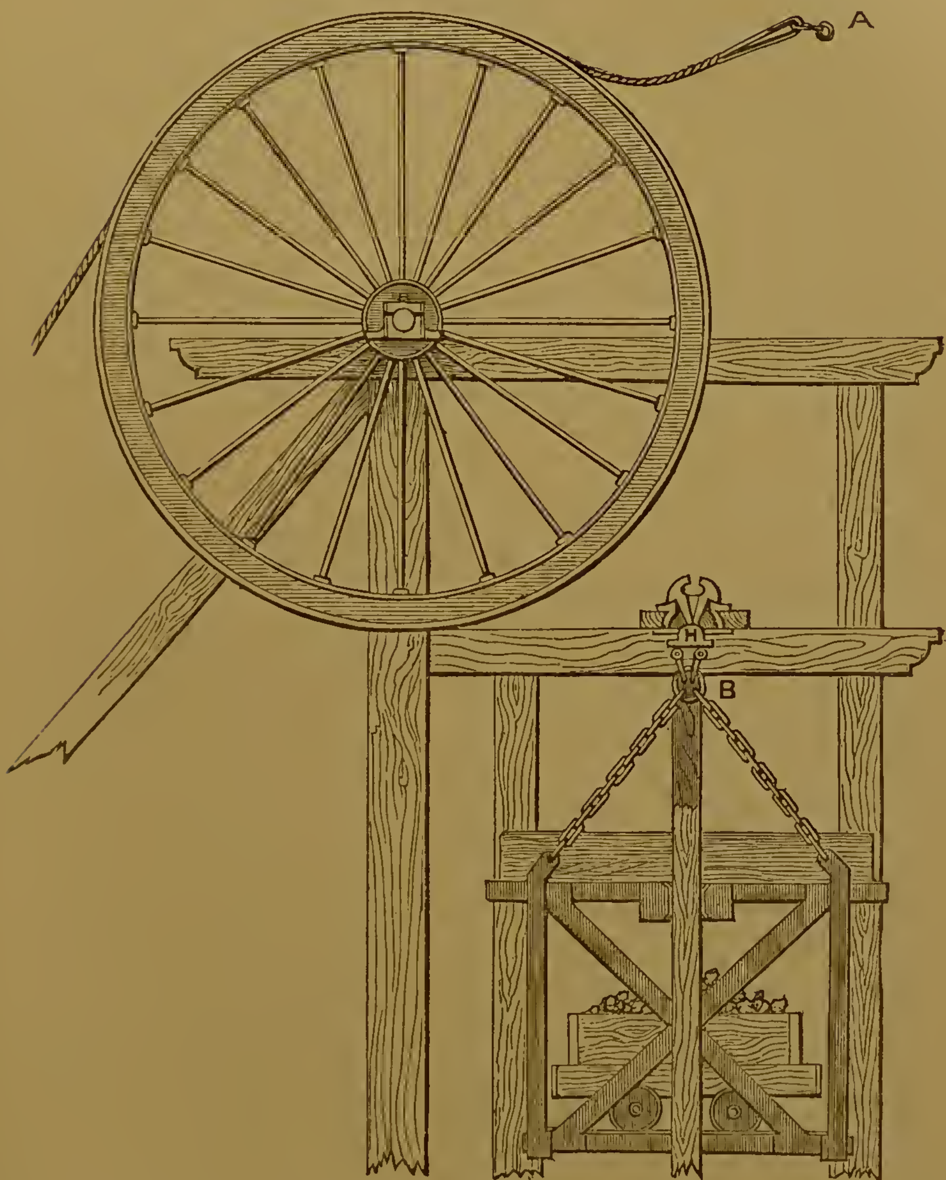
FIG. 9.



recommend it to be used in collieries, as all provision

for shaking of the framework when the engines are running is entirely ignored by the inventor.

Fig. 10.



The following description of the drawings will be found sufficiently explanatory :—

Fig. 5 is a front view of the hook.

Fig. 6 is an edge view of the hook.

Fig. 7 is a front view of the whole apparatus with the supporting ring and clamp in section.

Fig. 8 is an edge view of the same, with the supporting ring in section.

These last two figures show the hook just before and after the liberation of the lifting rope.

The same letters refer to the same parts in all the figures.

The lifting rope is attached to the shackle A, and the load to the connecting link B.

The supporting ring C (through which the rope is constantly working) is a fixture in a balk of timber or iron girder, at the pit top.

The hook consists of a pair of jaws D, D, working on a centre pin, E, in such a manner that the weight of the load has a tendency to open the upper limbs, which clip the strong centre pin of the shackle A. The upper limbs are formed externally with jaw hooks, F, F. The jaws are kept together and made to retain the shackle pin by means of the clamp H, which is held in position by the pins I, I.

In case of overwinding the jaw hooks (held together by the clamp) pass freely into the ring C, but the projections K, K of the clamp coming into contact with the bottom flange of the said ring hold the clamp stationary, while the jaws are being pulled through, the result being that the pins I, I are

sheared off, and the jaw hooks released from the restraint of the clamp. The internal diameter of the ring being the same as the width across the jaw hooks F, F, the rope remains secure, until the jaw hooks reach the top of the ring, when, by the action of the weight of the load, they are forced open, and so hook on to the top of the supporting ring C, as shown in fig. 8, the rope passing harmlessly over the pulley.

The recess O in the ring C is intended to meet an imaginary case that experiment shows to be almost impossible, namely, that if the engine is reversed after the pins I, I are cut, and before the hooks reach the top of the ring, the jaws will then hook into the recess and the load remain suspended in perfect safety.

It will be observed that the upper edge of the ring C is curved to match the sweep of the jaw hooks when opening. By this arrangement all shock is avoided.

Fig. 9 shows the apparatus applied to a pit in course of being sunk ; and fig. 10 the case of a regularly working pit, with the cage suspended by the detaching hook, in consequence of overwinding.

To complete the plans it will be necessary to give drawings here (figs. 11 and 12) showing the rings and balks of wood for supporting them and carrying the load after the rope is detached.

Fig. 11 is a plan showing two rings fixed in the timber at the proper distance apart to suit each rope.

FIG. 11.

FIG. 12.

Fig. 12 is a vertical section, showing the position of the rings in the timber, through the line A, B, where the balks are joined. The bolts C, C, for keeping the balks together, should be put through between the flanges of the ring.

It will at once be seen that a safety break is better than a detaching hook, as the former should never allow the latter to come into play. Great care should be taken in setting the break that if the hook does come into play the force shall be sufficient to cut the copper rivet and liberate the winding rope.

We will now describe what, in our opinion, is the best break extant. It is the invention of John Williamson, Esq., the manager of Cannock and Rugeley Colliery, where the break may be seen in operation at the Pool Pits.

It is a matter of frequent occurrence at a colliery, especially when the pit is working on short time, that the reversing lever of the winding engine is left in forward running gear instead of being reversed when the cages have been raised or lowered. Let us suppose that cage No. 1 is at the bottom of the pit, and cage No. 2 at bank; No. 1 is wanted at the top, and, the necessary signals having been exchanged, the engineer winds up No. 1 and lowers No. 2 simultaneously. Having brought his engine to a stand-still, unless he reverses the link gear when he starts, his engine No. 1 would be wound up into the head gear and dashed to pieces. It frequently happens, however, that he omits to do this at the time, and perhaps falls asleep, when, being signalled to wind, he wakes up in a hurry and starts his engine, and before he has discovered his mistake the accident happens. The winding rope may be provided with a detaching hook, but even then great delay is caused in getting everything straight again. To obviate this Mr. Williamson designed an Automatic Break. The break consists of a powerful block on the drum, and is put on and off by means of the revolution of the winding machinery. A spur-wheel is

geared on to the crank-shaft of the engine in such a manner that the revolutions of the latter are transmitted through the former to a screw, which screws on the break. The whole is connected with the reversing lever in such a manner that on the completion of each journey the break is hard on; and on reversing the lever, and so preparing to send No. 2 cage down and No. 1 up, the break is taken off immediately and the link gear of the engine reversed. If the engine-driver falls asleep, as supposed, and is woke up suddenly, he cannot make a mistake, as, if he tries to do so, he cannot start his engine, since he finds the break hard on, until he reverses; and the same thing occurs when the engine is in back-running gear.

In our opinion this break far exceeds anything in the form of a detaching hook, and its extreme simplicity of action cannot fail to make itself appreciated by colliery proprietors and managers. We have tried a series of experiments with it, and it is now in regular operation at Cannock and Rugeley Colliery. It can be set to come on and off at any point in the shaft, and with it over-winding is quite impossible.

CHAPTER XVIII.

THE ORGANISATION OF A LIFE BRIGADE FOR MINES.

We have in England, perhaps, without exception, the best and most efficient Fire Brigade, and without doubt the best Lifeboat Institution extant. The cost of appliances for maintaining fresh air in sufficient quantity for a gang of relief men to work in 'styth' or any deadly gas is so great, that they can hardly expect each colliery to have its own appliances. In Chapter IX. we examined several different aerophores, but we did not consider their cost.

In our opinion the Denayrouze High Pressure Aerophore is one of the appliances that should be considered.

The woodcut (fig. 13) shows the method of wearing the appliance.

The reservoir of fresh air is arranged as follows: Three steel cylinders are charged with air by a compressing pump; to these cylinders tubes and necessary valves are joined, to enable the wearer to breathe with comfort. A gauge is attached, which shows the wearer how long the air will last, and is attached to the air-tube leading from the receiver, and therefore independent of the atmosphere of the

mine. The complete apparatus for two men costs 186*l*.

FIG. 13.

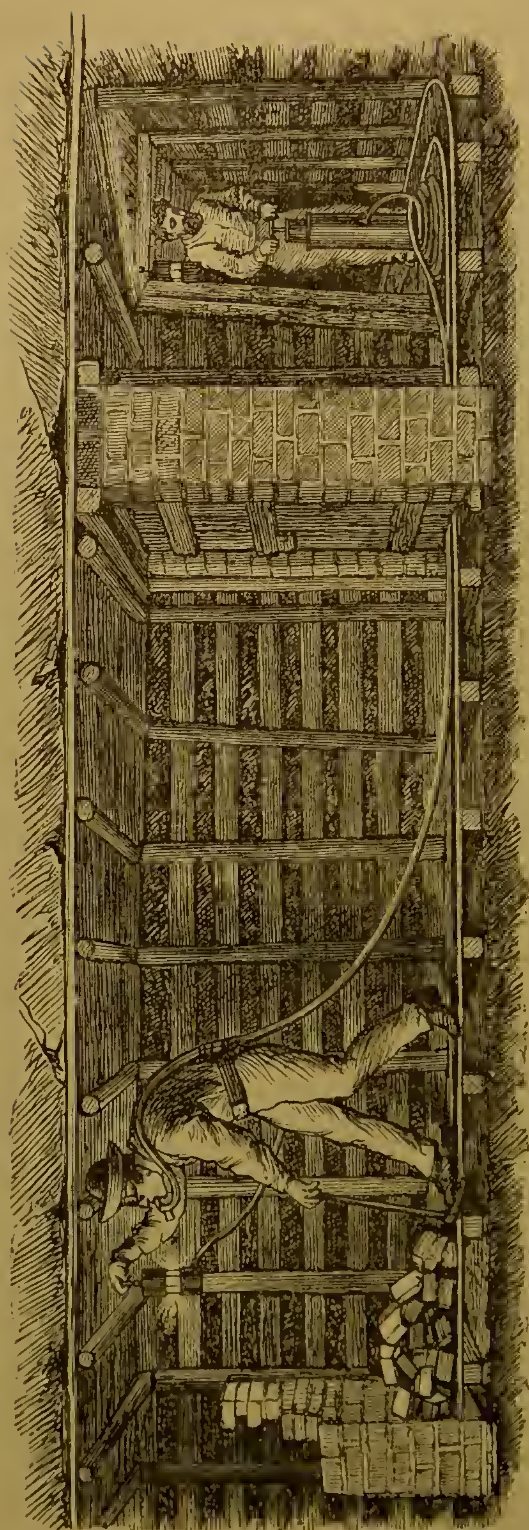
THE DENAYROUZE HIGH-PRESSURE ÆROPHORE.

It is suitable for about thirty minutes' urgent work, such as getting men out from the effects of after-damp, erecting a stopping, laying on brattice, etc. The advantage is obvious, since two men can enter a heading without dragging a long tube after them. Anyone who has had to undergo this inconvenience will know the danger there is in retracing steps, and getting the air-tube entangled round a prop or a piece of iron rail. We would caution those who have to use such appliances as this, and recommend them never to attempt to retrace their steps in a mine without first taking the air-tube in two coils in their hand, and coiling it up as they retreat; not with a view of keeping it out of the way, but because, should the air suddenly become cut off, the cause may be readily found by passing the hand along the pipe, and following the course until the cause of the obstruction is reached.

The next appliance and *modus operandi* is illustrated in fig. 14. It is also an invention of M. Denayrouze, and consists of a bellows pump, lamp, respirator, and eye protectors, joined up with suitable lengths of tubing. Here again the lamp is supplied with air from the pump. The whole of this arrangement complete, with 165 feet of tubing, costs 35*l*.

The following table will show the cost of equipping a relief gang such as I propose should be formed in the centre of mining districts:—

Fig. 14.



Men	Carrying	Cost
		£ s. d.
A* .	Aerophore	186 0 0
B, C	Bellows pump	35 0 0
D* .	Aerophore	Charged as above.
E* .	60 feet spare tube	6 0 0
F**, G**	Tools, brandy, lint, and stretcher	5 0 0
H o, I o, K o, L o, M o, N o, O o	Picks, timbering, and rope	Provided by the pit.
P w, Q w, R w	Hose	—
	Total	£232 0 0

The letters indicate men. Those marked * are engineers; **, deputies; o, hewers; w, pit carpenters.

Of course the number need not be limited to twenty only, but that number will be found sufficient for any relief or exploring party for immediate search or rescue. This gang is, as will be seen from the table, composed of twenty men, thus picked :—

3 engineers (two of whom would go in the 'face').
2 deputies (to direct with remaining engineers).
7 hewers (in case of fall, and as extra hands).
3 pit carpenters.

The whole of the aerophore tackle and appliances should be put in a box and kept at some central place, and the men at each pit shown how to use it. Really there is nothing to learn; all that is required is that the men who use it shall have plenty of the

true British pluck and determination to do what is required. Every pit should be made aware of the head-quarters of these brigades; and should an accident unfortunately occur, they should telegraph for the relief apparatus, the men being drawn from the pit. Those who are willing to serve and are proficient should have a distinctive mark, in order to insure competent men.

One deputy should live where the relief apparatus is stored. Of course this project would be met by certain men, who are against everything and propose no alteration, by the statement that we should not get the men. This statement is nonsense, for we have always drawn an exploring party from a crowd of lookers-on, mostly miners, by merely asking for them. The difficulty is to get the *first* man; and I would here advise every man who may be called upon to organise an exploring party, and where time lost means lives lost also, to arrange with one man before calling for men to volunteer, that on calling that man comes forward *at once.* If the man does not seem inclined to do this, select a married man, and then on completion of the number required refuse him, on the ground that he is married, and ask some one to take his place or do without him.

On descending the pit and arriving at the bottom, settle distinctly what is to be done before any men go 'in bye.'

We are confident that many lives might be saved

if such an organisation were got together in mining districts.

We raise annually say 140,000,000 tons of coal in Great Britain. If one penny per ton was charged upon coal an income of 583,333*l.* per annum would be derived. I think this organisation might be kept up on a tax of one penny on every ten tons raised. We would remind our readers that the question of lives lost in working and carrying coal is one that has occupied the public attention of late, and that if the public wish to lessen this loss of life they must be content to pay a little more for their coal than they did. We, as mining engineers, can find ways of lessening this loss of life if the public are prepared to find the means of paying for them.

If legislation interferes and says, 'Those collieries who cannot have the Guibal Fan are not to be worked till they do have it,' all that happens is the lessening of competition and consequent increase in the price of coal.

The whole subject has been treated very briefly here; in fact, there was no necessity for writing this book as far as regards those occupied in the profession of coal-mining. Our object in doing so was to try to set the whole matter in its true light before the public, with a view of showing what is done and what is required still to insure a maximum amount of safety for the miners. If we have succeeded we shall not consider our labour lost.

In conclusion, I would earnestly ask those whom it concerns to consider the use of explosives in mines; the timbering and propping of roofs in the hands of the stall-men; the stall-men finding their own powder; the practice of 'putting back' the small coal; and in considering them to discontinue them, if they think them 'dangerous practices not expressly forbidden in the Act.'

AN EXPLANATION OF SOME MINING TERMS.

Gob . . . / Goaf . .	Waste workings.
In bye . .	Into the workings.
Output . .	The amount of coal brought to the surface.
Out bye . .	Out of the workings towards the bottom of the shaft.
Outcrop . .	Coal is said to 'crop out' when it comes to the surface and ends.
Outburst . .	An outburst of gas is a sudden evolution of gas.
Long wall way .	Cutting the seam by driving a heading into it.
Rib and pillar . / Pillar and stall	Taking coal out in blocks, say 20 yards square, alternately leaving a block and taking one.
Tubs . . .	Wagons in which the coal is brought up.
Upcast (shaft) .	Shaft up which the foul air comes.
Styth . .	After-damp.

List of Coal-laden Vessels which Sailed from the United Kingdom for Foreign Port in th

Date of Clearance or Sailing	Name of Vessel	Owners	Flag	Tonnage	How long built	Wood or Iron	Class	Port of Loading
1874				Tons				
Feb. 11	Antigua	J. Kerr & Co.	British	643	16 years	Wood	A1	Greenock
Mar. 31	Lady Louisa	Wilson & Co.	British	542	9 "	Wood	A1	Cardiff
April 22	Mogul	J. H. Sears & Co.	American	1,320	5 "	Wood	A1 America	Liverpool
" 29	Lucayas	T. O. Hunter	British	446	5 "	Iron	*A1	Dundee
" 30	Lady Heathcote	J. Ransom	British	498	6 "	Wood	A1	Cardiff
May 2	Centaur	Fletcher & Co.	British	1,212	10 "	Iron	*A1	Liverpool
" 2	Noumea	Matthieu & Co.	French	1,155	12 "	Iron	*A1	Newcastle
" 4	Anna	. . .	Dutch	969	. .	Wood	. . .	Cardiff
" 6	Unione	Vianello Bros.	Italian	560	6 "	Wood	3·3	Shields, N.
" 8	Mary Goodell	W. McGilvery	American	761	20 "	Wood	5·6	Greenock
" 26	Androcles	. . .	Greek	288	. .	. .	. . .	Swansea
June 1	John Elliot	J. Malcolm	British	1,198	9 "	Wood	A1	Dundee
" 10	Susanna Johanna	Von Zeylen & Co.	Dutch	1,145	15 "	Wood	A1 (red)	Newcastle
" 10	Euxine	E. P. Bates	British	1,594	27 "	Iron	A 1	Newcastle
" 12	Palmyra	W. Thompson	British	932	5 "	Wood	A	Liverpool
" 12	Michael	P. A. Cocali	Greek	312	19 "	Wood	. . .	Swansea
" 13	Maasluis	G. H. Uitden-Boogaardt	Dutch	797	8 "	Wood	3·3	Newcastle
" 16	Oliver Cromwell	W. R. Price & Co.	British	1,112	8 "	Wood	A1	Newcastle
" 19	Eeta	W. & J. Smith	British	331	6 mths.	Wood	A1	London
" 22	Alexandre	A. Bordes	French	26	5 years	Iron	*A1	Liverpool
" 22	Brenhilda	Hendry, Ferguson, & Co.	British	1,320	1 month	Iron	100 A 1	Glasgow
" 26	Merchant	I. S. Tumulty.	British	1,059	12 years	Wood	. . .	Liverpool
" 27	Moss Trooper	Ismay & Co.	British	510	10 "	Wood	A1	Liverpool
" 27	Admiral Fitzroy	Burgess & Co.	British	377	10 "	Wood	A1	Cardiff
" 27	Genitore	. . .	Italian	508	. .	. .	. . .	Hull
" 29	David Brown	P. Pendleton, Jun.	American	905	10 "	Wood	A1 America	Cardiff
" 30	Calcutta	W. R. Price & Co.	British	1,372	10 "	Wood	A1	Newcastle
July	Sierra Nevada	H. D. & J. Brookman	American	1,672	11 "	Wood	3·3 A	Liverpool
" 3	County of Perth	R. & J. Craig	British	1,626	1 month	Iron	100 A 1	Glasgow
" 4	Waldridge (s.)	Clark & Co.	British	432	6 years	Iron	A1	Sunderland
" 8	Pocahontas	W. Dixon	British	1,132	19 "	Wood	. . .	Newcastle
" 9	Willie S. Thompson	R. Thompson	British	846	2 "	Wood	3·3L	Newcastle
" 10	Camano	. . .	Italian	487	2 "	Wood	3·3 A	Liverpool
" 10	Dumbartonshire	T. Law & Co.	British	914	2 mths.	Iron	100 A 1	Glasgow
" 10	Workington	Hargrove & Co.	British	1,252	1 month	Iron	100 A 1	Port Glasgow
" 13	Industry	R. Robbins	British	1,138	16 years	Wood	. . .	Newcastle
" 13	Blair Athol	Thomson & Co.	British	1,697	1 month	Iron	100 A 1	Glasgow
" 15	Mendora	Stoddart Brothers	British	970	9 years	Wood	A1	Liverpool
" 16	Staffordshire	D. Stuart & Co.	British	1,167	12 "	Iron	*A1	Liverpool

ing the year 1874 *to which Casualties occurred through Spontaneous Combustion*
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Port of Destination	Quantity Shipped	Description of Coal	How loaded, Barrows or Tips	Whether ventilated and how	How long Coal had been on board	Supposed Cause and Extent of Casualty	Lives lost, so far as reported	Weather when loading
	Tons							
a . .	910	—	—	—	—	—	—	—
nghai .	800	Powell Duffryn . .	. . .	Ventilated .	181 days	—	—	—
Francisco	1,555	Barnes's Lancashire .	Tips	. . .	3 mths.	Total loss	—	—
utta .	680	Auldton Ell Coal .	. . .	. . .	4 „	—	—	—
lera .	527	Insoles, No. 3 Rhonda .	. . .	Ventilated .	2 „	Total loss	—	—
Francisco	1,310	Barnes's Lancashire .	Tips	. . .	Over 2 months	Total loss .	16	—
lras .	1,530	Cowpen Hartley . .	. . .	Ventilated .	115 days	Damaged	—	—
gapore .	1,420	Insoles Merthyr steam coal, double screened	Wagons, very slight fall	Well ventilated	60 „	Cargo damaged; part thrown overboard	.	Fine and dry
lao . .	784	. . . . . .	. . .	. . .	. .	Damaged	—	—
Janeiro .	998	. . . . . .	. . .	. . .	. .	Damaged	—	—
ssa .	406	. . . . . .	. . .	. . .	. .	Damaged	—	—
cutta .	1,706	Auldton steam coal .	. . .	Well ventilated	3 mths.	Total loss	—	—
ieen .	1,600	Hartley coal .	. . .	Ventilated .	. .	Total loss	—	—
en . .	2,062	Howard's West Hartley .	Tips and shoot	Iron permanent ventilators; wooden additional ones.	60 days	Total loss .	4	Fine
dras .	1,206	Hartley steam coal .	Tips	Ventilated .	3 mths.	Damaged	—	—
xandria .	483	. . . . . .	. . .	. . .	. .	Vessel sold		—
ieen .	1,160	Bower's West Hartley .	. . .	. . .	. .	Cargo heated	—	—
en . .	1,530	Howard's West Hartley .	Tip	Thoroughly ventilated	83 days	Nature of coal; total loss	.	Fine
bice .	288	Swadlincote, 106 tons . Baddersley 50 „ Babbington 96 „	Baskets	Well ventilated	38 days	Ship saved	—	—
lparaiso .	1,135	Lancashire best Orrell steam coal, double screened	Wagon	Well ventilated	2 mths.	Damaged	—	—
cutta .	1,766	Ell coal . . .	Wagon	Well ventilated	7 weeks	Coal too fresh from pits; cargo heated	.	Very fine
apulco .	1,448	N. Wales . . .	. . .	. . .	. .	Damaged	—	—
lparaiso .	685	Ince coal, 4 feet seam .	. . .	Well ventilated	3 mths.	Total loss	—	—
lparaiso .	521	Insoles, No. 3 Rhonda, worked from Cymmer colliery, and from No. 3 Rhonda seam, through and through	Wagon	Cargo divided by deal boarding	10 weeks	Total loss .	.	Wet
essa .	838	. . . . . .	. . .	. . .	. .	Total loss	—	—
gapore .	1,233	Merthyr steam coal .	. . .	. . .	. .	Cargo heated	—	—
en . .	1,800	Howard's West Hartley .	Tips	Thoroughly ventilated	80 days	Nature of coal; total loss		Fine
n Francisco	1,392	Barnes's Lancashire .	Tips	. . .	40 „	Total loss	—	—
lcutta .	1,617	Roughrigg's steam coal, double screened	Barrows, fall 27 feet	Well ventilated; wood and iron	114 „	. . .	.	Dry
nstadt .	850	. . . . . .	. . .	. . .	. .	Cargo heated	—	—
mbay .	1,579	Hasting's Hartley .	. . .	Well ventilated	65 days	Total loss	—	—
ique .	1,300	West Hartley .	. . .	Ventilated .	3 mths.	Total loss .	7	—
essa .	807	—	—	—	—	—	—	—
enos Ayres	530	Splint coal, Russell's colliery . . .	Barrows	Partially ventilated	2 mths.	Damaged .	.	Good Weather
n Francisco	1,640	Splint coal, mixed. Woodside field, Hellfield, Lougher field, and Skellyton field	. . .	Ventilated .	56 days	Vessel and cargo sold	—	—
mbay .	1,455	Davidson's West Hartley steam coal from Bidlington colliery, probably low main seam, single screened	Waggon and spout	Carefully ventilated	98 „	Freshness of coal; total loss	.	Fine and dry
mbay .	2,249	Watson's Hartley .	. . .	Well ventilated	2¼ mths.	Cargo heated	—	—
mbay .	1,160	Tryddyn colliery, Coed Talon	. . .	Ventilated .	2½ „	Damaged	—	—
n Francisco	814	Lancashire steam coal, White Moss coal, single screened	From high level. Only slight fall	Ventilated (wood)	100 days	Newness of coal; damaged	.	Very fine

List of Coal-laden Vessels which Sailed from the United Kingdom for Foreign Po[rts] in the Ca[...]

Date of Clearance or Sailing	Name of Vessel	Owners	Flag	Tonnage	How long built	Wood or Iron	Class	Port of Loading
1874				Tons				
July 21	Victorine . .	Lequellec & Bordes .	French .	1,621	16 years	Comp.	. . .	Liverpool
,, 22	Go-ahead . .	C. Ahrens . .	German .	385	20 ,,	Wood	. . .	Liverpool
,, 24	Pelligrina . .	G. Mortola . .	Italian .	319	13 ,,	Wood	. . .	Swansea
,, 27	Alpha . .	Bath & Co. . .	British .	397	10 ,,	Wood	A1	Swansea
,, 28	Glentilt . .	Hughes & Co. . .	British .	991	9 ,,	Wood	A1	Cardiff
,, 30	Glory-of-the-Seas .	J. H. Sears & Co. .	American	2,102	5 ,,	Wood	A1 America	Liverpool
,, 30	Ermenigilda Danovaro	A. Danovare . .	Italian .	813	19 ,,	Wood	5·6 A	Cardiff
Aug. 4	Laine. . .	C. A. Berntedt .	Russian .	520	8 ,,	Wood	3·3 A	Hull .
,, 6	Ontario . .	Stuckey & Co. .	British .	1,062	13 ,,	Wood	. . .	Shields, So.
,, 6	Ascolta . .	F. Marciani . .	Italian .	302	9 ,,	Wood	. . .	Hull .
,, 10	Respigadera. .	Hargroove & Co. .	British .	1,629	1 month	Iron	20 (red)	Sunderland
,, 13	Northbrooke .	Adamson & Ronaldson	British .	1,820	4 mths.	Iron	100 A1	Shields, No.
,, 13	New Lampedo .	T. Seed . .	British .	1,099	10 years	Wood	A2 America	Liverpool
,, 14	Enthusiast . .	J. Ditchburn . .	British .	283	20 ,,	Wood	A1	London
,, 15	Monmouthshire .	D. Stuart . .	British .	1,161	11 ,,	Wood	. . .	Liverpool
,, 19	La Escoscsa. .	Balfour & Co. . .	British .	946	6 ,,	Iron	A1	Cardiff
,, 24	Clothilde . .		Italian .	568	. .	. .	. . .	Cardiff
,, 29	St. Nicholas. .	Chapman & Flint .	American	1,798	5 ,,	Wood	3/3 A	Liverpool
About end of August	Skandia . .	. . . .	Finn .	281	. .	Wood	. . .	Gloucester
Sept. 4	Try . . .	W. & J. Wright .	British .	428	,,	Wood	A	London
,, 5	Crystal . .	W. & J. Wright .	British .	263	2 ,,	Wood	A1	London
,, 15	Khersonese . .	G. Duncan . .	British .	1,710	19 ,,		100 A 1	Newcastle
,, 18	P. J. F. Burchard .	L. Burchard & Son .	German .	459	13 ,,	Wood	. . .	Leith .
,, 19	The Foundling .	E. Bates . .	British .	1,185	8 ,,	Iron	A1	Liverpool
,, 28	May Queen . .	Thompson . .	British .	1,055	12 ,,	Wood	A1	Newcastle
,, 29	Chili . . .	. . . .	French .	1,441	. .	. .	. . .	Liverpool
Oct. 2	Eugenie . .	. . . .	German .	734	. .	Iron	. . .	Liverpool
,, 3	Levant . .	Jones & Co. . .	British .	314	8 ,,	Wood	A1	Swansea
,, 5	Tilde . . .	A. Poschich . .	Austrian.	636	10 mths.	Wood	A1	Hull .
,, 16	Fedelma . .	Scrutton, Sons & Co.	British .	478	5 years	Iron	* A1	Porthcawl
,, 23	City of Richmond .	D. Kennedy . .	British .	1,241	10 ,,	Wood	. . .	Liverpool

-ing the year 1874 *to which Casualties occurred through Spontaneous Combustion* —Continued.

Port of -stination	Quantity Shipped	Description of Coal	How loaded, Barrows or Tips	Whether ventilated, and how	How long Coal had been on board	Supposed Cause and Extent of Casualty	Lives lost, so far as reported	Weather when loading
	Tons							
-paraiso .	2,480	Orrell steam coal . .	Tips	Well ventilated	. .	Cargo fired	—	—
-istntinople	602	. . . . . .	. . .	. . .	89 days	Damaged	—	—
-cus .	521	. . . . . .	. . .	. . .	. .	Damaged	—	—
-paraiso .	550	Rhonda, No. 3 . .	. . .	. . .	2 mths.	Damaged	—	—
-uimbo .	607	Non-screened smelting coal, Penygraig colliery	By shoot	Ventilated with platforms under cargo	103 days	Inferior quality and damp state of coal	.	Very fine and dry
Francisco	2,100	Barnes's Lancashire .	Tips	. . .	. .	Cargo heated	—	—
-paraiso .	1,102	No. 3, Rhonda (smelting coal)	. . .	. . .	. .	Damaged	—	—
-iens .	781	. . . . . .	. . .	. . .	. .	Vessel sold	—	—
-nbay .	1,526	West Hartley, Main coal	Tips	Well ventilated	5½ mths.	Damaged .	.	Fine, but showery
-istntinople	527	. . . . . .	. . .	. . .	. .	Total loss	—	—
Francisco	1,974	Cowpen Hartley . .	. . .	Well ventilated	. .	Damaged	—	—
-dras .	1,657	Cowpen Hartley, and Hastings Hartley .	. . .	Well ventilated	4 mths.	Damp state of coal	.	Changeable
-nama .	1,499	Barnes's Lancashire .	Tips	Deck ventilators fore and aft; grain lining left in 'tween decks	3 ,,	Total loss .	.	Very wet
-merara .	193	Swadlincote, (single screened)	Basket	. . .	53 days	Total loss	—	—
. Francisco	1,385	Barnes's Lancashire .	Tips	Well ventilated	6 weeks	Damaged	—	—
-paraiso .	1,453	No. 3, Rhonda . .	Tips	Well ventilated (Venetian ventilators)	130 days	Coal green and wet, damaged	.	Raining heavily
-lparaiso .	751	Rhonda, No. 3 . .	. . .	. . .	. .	Total loss	—	—
-Francisco	2,015	Brancker's, Pemberton coal	Tips	Ventilated and platformed	3½ mths.	Damaged	—	—
-penhagen .	250	. . . . . .	. . .	. . .	6 weeks	Vessel damaged	—	—
-merara .	107	57 tons Swadlincote . 50 ,, Stockley Hall .	Basket From craft	Probably (not certain)	60 days	Cargo heated	—	—
-rbice River (New Amsterdam)	239	136 ,, Swadlincote . 102 ,, Stockley Hall .	Basket From lighter	Ventilated .	80 ,,	Cargo heated	—	—
-mbay .	2,000	Bebside West Hartley, double screened	. . .	Well ventilated	160 ,,	—	—	—
-nte Video	720	Splint coal	—	—	—	—	—	—
-mbay .	1,281	Mixed:—795 tons Westminster Brymbo; 306 tons Oak Pits coals; 200 tons coke . .	Tip and shoot	Permanent iron ventilation; additional wooden ones	2 mths.	Total loss .	.	Wet
-ngoon .	1,415	Cowpen Hartley . .	. . .	. . .	153 days	Total loss	—	—
-lparaiso .	2,000	Orrell steam coal . .	Tips	Ventilated .	3 weeks	—	—	—
-lparaiso .	860	. . . . . .	. . .	. . .	. .	Damaged	—	—
-lparaiso .	470	Smelting coal; not screened	Wagon, 20 ft. fall	Ventilated with wood	100 days	Damaged .	.	Partly wet
-ulmein .	869	—	—	—	—	—	—	—
-lparaiso .	654	Smelting coal from the 'Aber Coal Co.,' not screened	Tip	Cargo was divided fore and aft by stanchions from deck to kelson, and ½-in. boards nailed to them, thus leaving space 6 inches broad from top to bottom, dividing the whole cargo in the middle	. .	Fire; slight damage	.	Fine and dry
-mbay .	1,638	Laisols' West Hartley, double screened	Tip	Well ventilated and platformed	142 days	Cargo in state of combustion	—	—

List of Coal-laden Vessels which Sailed from the United Kingdom for Foreign Po
in

Date of Clearance or Sailing	Name of Vessel	Owners	Flag	Tonnage	How long built	Wood or Iron	Class	Port of Loading
1875 March 9	Quatters Fratelli .	Dillorto Frères, Genoa	Italian .	Tons 500	6 years	Wood	3/3 A	Cardiff
„ 18	Independenza .	G. Lisario, Malta .	Italian .	505	18 „	Wood	. . .	Cardiff
April 24	Angelo Antonio .	E. Razetto, Genoa .	Italian .	598	5 „	Wood	. . .	Liverpool
„ 27	Pilgrim . .	H. Hastings, Boston, U.S.	American	1,050	1 „	Wood	1 America	Shields
May 13	Antelope .	B. McNear & Co., Boston, U.S.	American	1,306	2 „	Wood	3/3 L	Clyde .
June 3	Frankfurt Hall .	W. P. Coleborn, 2 Tower Chambers, Liverpool	British .	728	6 „	Iron	*A1	Liverpool
„ 5	Helen Morris .	C. T. Child & Co., New York	American	1,285	7 „	Wood	1 America	Shields
„ 8	Senator . .	. . . .	American	.	. .	Wood	. . .	Philadelphi
„ 8	Willem Poolman .	Van Zeyland & Co., Rotterdam	Dutch .	1,244	9 „	Wood	A	Shields
„ 18	Aracana . .	G. N. Roberts, St. John's, N.B.	British .	1,192	13 „	Wood	2[1] America	Liverpool
„ 20	Aurelie . .	Etienne Michon, Quebec	American	546	6 „	Wood	L 11 Veritas	Liverpool
„ 25	Clevedon . .	E. C. Friend, 2 Tower Chambers, Liverpool	British .	698	7 „	Iron	*A1	Liverpool
„ 30	Martin Wienert .	J. Johnasson, 5 Gloucester Square, London	British .	506	3 „	Iron	90 A 1	Shields
July 10	Dominicho Galliano	Galliano Fils, Genoa	Italian .	537	10 „	Wood	3/3 A	Cardiff
„ 16	River Boyne .	J. Hargrove, Hargrave's Buildings, Chapel Street, Liverpool	British .	499	8 „	Iron	*A1	Liverpool

This vessel ailed again August 31 from the Tyne for Hamburg with coal, and was published as missing in Lloyd's L
off the Doggerbank; and in Lloyd's List of September 10 there is a paragraph stating that it w

ring the year 1875, *to which Casualties occurred through Spontaneous Combustion* al.

Port of Destination	Quantity Shipped	Description of Coal	How loaded, Barrows or Tips	Whether ventilated, and how	How long Coal had been on board	Supposed Cause and Extent of Casualty	Lives lost, so far as reported	Weather when loading
llao .	Tons 790	279 tons of Rhondda, No. 3; 511 tons of Aber Rhondda, No. 2	. . .	. . .	. .	Fire; vessel damaged; cargo sold	—	—
lparaiso .	860	Aber Rhondda, No. 2 .	. . .	. . .	. .	Cargo much heated	—	—
llao .	900	Best Orrell coal . .	. . .	. . .	9 weeks	Burnt; total loss	—	—
ong Kong .	1,404	Cowpen's West Hartley .	By spout	Ship ventilated fore and aft; no ventilators for cargo	Nearly 5 months	Fire under main hatch; slight damage	.	Fine.
n Francisco	1,273	Lanarkshire hard splint coal from Mr. John Watson's pits	. . .	. . .	Nearly 5 months	Took fire whilst discharging; vessel damaged	—	—
alparaiso .	602	Shipper's state steam coal from Tawd Vale Colliery, 7-ft. seam. Double screened	Wagon	Eight mooring bitts constructed as ventilators, and three large open galvanised iron ventilators	Nearly 4 months	Fire; cargo damaged	.	Fine and dry
n Francisco	1,650	Cowpen West Hartley steam coal	. . .	. . .	Nearly 6 months	Burnt; total loss	—	—
nama .	1,600	. . . . .	. . .	Ventilators below the hatches	3 mths.	Burnt; total loss	2	—
va . .	1,600	. . . . .	. . .	. . .	. .	Burnt; total loss	—	—
ombay .	1,756	. . . . .	. . .	. . .	4 mths.	Burnt; total loss	—	—
rbadoes .	701	Bituminous steam coal .	. . .	Ventilated by hatches; no ventilators for cargo	6 weeks	Burnt; total loss	.	Fine.
alparaiso .	1,037	Shippers state steam coal from Tawd Vale and Crow Orchard Collieries, 7-ft. seam. Double screened	250 tons by lighter, rest by boxes from tips	Eight mooring bitts constructed as ventilators, and three large open galvanised iron ventilators through deck	3 mths.	Burnt; total loss	.	Fine while loading, heavy weather off Cape Horn
'Uhlgraben .	1,018	Bebside screened Hartley steam coals	From wagon by spout	All holds and other parts of vessel ventilated by several metal pipes carried above deck and having swan necks	A week	Fire; slight damage; part cargo jettisoned	.	Good weather
ngapore .	812	Large steam coal . .	. . .	. . .	3 mths.	Fire; vessel much damaged	—	—
alparaiso .	766	Orrell coal . . .	. . .	Hatches, &c., forward and aft	3 "	Fire; part cargo jettisoned	—	—

October 7. In Lloyd's List of September 9 a report appears of a lifeboat belonging to this vessel having been picked up ported that an explosion had taken place, causing her to founder, and that there were 22 hands on board.

List of Coal-laden Vessels which Sailed from the United Kingdom for Foreign Po[rts] in the Co[...]

Date of Clearance or Sailing	Name of Vessel	Owners	Flag	Tonnage	How long built	Wood or Iron	Class	Port of Loading
July 25	Powhattan . .	G. Meager, Swansea.	British .	Tons 399	9 years	Wood	A1	Swansea
Aug. 14	Beucleugh . .	W. Thomson, Alloa.	British .	1,350	4 mnths.	Iron	100 A 1	Greenock
Sept. 18	Aberaman . .	Capper & Alexander, Cardiff	British .	1,090	6 ,,	Iron	100 A 1	Shields
,, 25	Theresa . .	B. French, 44 Castle Street, Liverpool	British .	704	18 years	Wood	5/6 L 11 in Veritas	Birkenhead
Oct. 10	Le Baron . .	J. W. Paynter, Liverpool	British .	907	5 ,,	Wood	. . .	Hull .
,, 16	Patmos . .	Lunt Bros. & Co., Newbury Port, U.S.	American	738	16 ,,	Wood	1[1] America	Hull .
—	Utrecht . .	Van Zeyland & Dreker	Dutch .	1,873	7 ,,	Wood	A1	Newcastle
—	Mabel . .	C. Hill & Son, Bristol	British .	429	2 ,,	Wood	A1	Porthcawl
Sept. 18	San Rafael . .	Balfour, Williams, & Co., Liverpool	British .	955	13 ,,	Wood	A1 America	Liverpool
—	Fanny . .	H. Holmes, Bishopswearmouth	British .	398	12 ,,	Wood	A1	Porthcawl
Dec. 26	John Clarke .	. . . .	American	1,079	19 ,,	Wood	1[3] America	Liverpool

ng the year 1875, *to which Casualties occurred through Spontaneous Combustion*
ontinued.

ort of ination	Quantity Shipped	Description of Coal	How loaded, Barrows or Tips	Whether ventilated, and how	How long Coal had been on board	Supposed Cause and Extent of Casualty	Lives lost, so far as reported	Weather when loading
araiso .	Tons 580	Smelting, Trycher, through and through	Shoot	Ventilated bulkhead to bulkhead with deals from keelson to deck	11 weeks	Cargo heated; part jettisoned	.	Very fine
ay .	1,781	Watson's Hartley .	By wagon and steam crane	In addition to ventilation suitable for emigrant trade she had four wooden venetianed ventilators down to ceiling	3 mths.	Fire; part cargo jettisoned	.	Wet weather
ay .	1,620	Cowpen Hartley steam coal, single screened	Tips	Ventilated through masts, bitts, &c., and iron ventilators both ends of ship with cowls	4 ,,	Cargo much heated, almost on point of ignition	.	Fine
oon .	920	Chill Colliery Co., Thurstall, Staffordshire	From tips	Excessively ventilated; square venetianed deal ventilator in each hatch to keelson, and a trunkway on each side of keelson, and three rose-mushroom ventilators in each hatch	2½ ,,	Burnt; total loss	.	Part of the time raining
raiso .	1,378	Steam coal of second class. West Riding screened Hartley, Messrs. Pope & Pearson's pit near Normanton	. . .	. . .	. .	Burnt; total loss	1	Fine
araiso .	.	Steam coal second class. Featherstone's Main Hartley Colliery	. . .	. . .	. .	Burnt; total loss	—	—
ia .	.	. . . . .	. . .	. . .	2 mths.	Fire; jettisoned part cargo	—	—
ra .	647	Through and through smelting coal	Tip and shoot	Boarded longitudinally from keelson to upper deck having space between, also platform 14 or 15 inches high	3 ,,	Fire; slight damage	.	Variable
raiso .	1,300	. . . . .	. . .	A ventilator in each hatch	3 ,,	Burnt; total loss	10	Fine and close
raiso .	.	. . . . .	. . .	. . .	Not known; casualty occurred Dec. 28, 1875	Fire; great damage	—	—
ay .	1,343	. . . . .	. . .	. . .	4½ mths.	Fire	—	—

List of Coal-laden Vessels Posted at Lloyd's as Missing, having Sailed from the United Kingdom during the years 1874 *and* 1875 *on over-sea Voyages.*

Date of Sailing	Vessel	Tonnage	Voyage		Date of Lloyd's List when posted as Missing
1874					
January 17	Sidra (s)	923	Shields	Port Said	March 26, 1874
February 1	Pilgrim	182	Mostyn	Santander	May 7, 1874
" 3	Lydia	100	Ayr	Malaga	July 30, 1874
" 6	Alejandro	436	Newport	Hong Kong	December 3, 1874
" 6	Alida	313	Liverpool	Buenos Ayres	Part coal
" 6	George Duekles	172	Liverpool	Lagos	September 24, 1874 (part coal)
" 7	Eliza Thornton	429	Cardiff	Cadiz	August 20, 1874
" 9	Zelie	172	Cardiff	Bordeaux	May 7, 1874
" 9	Auua	75	Liverpool	Reikjavik	July 30, 1874 (part coal)
March 18	Maria	197	Tyne	Stockholm	July 9, 1874
" 20	Forest King	1,085	Newcastle	Rio Janeiro	September 24, 1874
" 24	Sea Queen	372	Liverpool	Genoa and Rio Janeiro	July 30, 1874
" 31	Rhuma	138	Liverpool	Lisbon	July 9, 1874
April 1	Everdina	212	Sunderland	Stockholm	August 13, 1874
" 2	Franklyn	284	Peterhead	Iceland	August 6, 1874
" 4	Freak	99	Shields	Cadiz	July 30, 1874
" 6	Raven	101	Cardiff	Lisbon	October 8, 1874
" 7	Speedwell	668	Cardiff	Malta	August 13, 1874
" 7	Myrtle	417	Sunderland	Palermo	August 13, 1874
" 8	Atlantie	996	Liverpool	Aden	November 12, 1874
" 8	Eliza Forbes	149	Tyne	Stralsund	July 16, 1874
" 9	May Queen (s)	577	Tyne	Carthagena	May 28, 1874
" 9	Hyaline	171	Newcastle	Guadeloupe	December 3, 1874
" 10	The Barton (s)	417	Greenock	Licata	June 11, 1874
" 11	Pontiac	1,050	Sunderland	Bombay	December 10, 1874
" 12	Jules de Rontaunay	437	Cardiff	Bahia	November 12, 1874
June 17	North Glen	499	Liverpool	Caldera	March 11, 1875 (part coal)
July 13	Eastern Star	340	Troon	Singapore	April 1, 1875
" 15	Maypocho	699	Liverpool	Valparaiso	March 4, 1875
August 15	Carmainia	729	Liverpool	Valparaiso	March 25, 1875
September 23	Isabella Kerr	1,415	Greenock	Bombay	May 20, 1875
October 13	Nora Graeme	1,001	Liverpool	Bombay	June 3, 1875
" 16	St. Mirren	526	Troon	Demerara	February 25, 1875 (part coal)
November 7	Romeo	210	Granton	Berbice	April 9, 1875
" 20	Auna	157	Cardiff	Villafranca	July 8, 1875
" 27	Success	474	Liverpool	Shanghai	September 2, 1875
" 28	Solide	291	Cardiff	Port Mahon	May 14, 1875
" 30	Ann Mitehell	189	Cardiff	Bari	April 22, 1875 (part coal)
Deeember 5	Aliee (s)	627	Cardiff	Constantinople	March 18, 1875
" 5	Alfred	79	Swausea	Granville	March 11, 1875
" 15	Argosy	394	Shields	Mauritius	August 5, 1875 (part coal)
" 31	Marmion	292	Tyne	Bueuos Ayres	July 8, 1875
1875					
January 10	Hans Christen Orsted	163	Tyne	Messina	May 27, 1875
" 22	George Batters (s)	714	Porthcawl	Gibraltar	March 18, 1875
June 7	Lothair	859	Liverpool	Valparaiso	June 29, 1876
July 27	Rosewood	276	Troon	Mantanzas	December 30, 1875
August 31	Martin Wiener (s)	755	Tyne	Hamburg	October 7, 1875
September 24	Mette	91	Tyne	Korsoer	December 16, 1875
October 26	Acapulco	598	Liverpool	Valparaiso	June 15, 1876
November 8 (Yokohama Roads)	Yokohama	154	Tyne	Rotterdam	January 13, 1876
November 9	Cavalier (s)	115	Swansea	Nantes	December 16, 1875
" 15	Lousitania	206	Newcastle	Oporto	March 2, 1876
" 20	Benton	952	Birkenhead	Bombay	July 6, 1876
December 3	Magic	180	Tyne	Lisbon	March 9, 1876

This List is made up to July 6, 1876; but there may be other Vessels posted as Missing during the remainder of the year 1876, which had sailed in the year 1875.
Vessels with Patent Fuel not included in the List.

Summaries of the Statistical Portions of the Reports of Her Majesty's Inspectors of Mines for the Year 1876.

The Reports are each made separately to the Right Honourable R. A. Cross, M.P., Her Majesty's Principal Secretary of State for the Home Dapartment. The statistics are collated by the Inspectors from figures supplied by each Inspector.

Coal Mines Regulation Act.

The summaries of the statistics for the twelve districts consist of four separate documents in tabular form, showing the aggregate numer of persons employed during the year above and below ground in the coal, fireclay, ironstone, and shale mines of Great Britain and Ireland.

The 1st summary shows the number and ages of the male persons employed, both above and below ground, and also the number and ages of the females employed above ground, together with the quantity of mineral raised in each of the twelve Inspection Districts. It appears that in the aggregate 514,532 persons were employed in and about the mines already mentioned herein. Of these 409,229 were employed underground, and 105,303 (of whom 6,055 were females) employed above ground; thus showing,

as compared with the respective numbers employed during the year 1875, a decrease of 21,313, namely, males 20,864, and females 449.

2nd. This summary gives the mining produce, either in districts or counties, by which it appears that 134,125,166 tons of coal, 2,071,983 tons of fire-clay, 12,159,580 tons of ironstone, and 632,656 tons of shale, etc., were produced in the mines classed under the Coal Mines Regulation Act, including the quantity of iron pyrites, etc. found in working these mines, which is separately given in the respective districts to which these latter remarks apply. Comparing the above quantities with the output of 1875, an increase is shown in coal of 818,681 tons; fire-clay, an increase of 139,689 tons; ironstone, an increase of 140,986 tons, and an increase also of 189,716 tons in the quantity of shale, etc.; thus giving an augmented quantity of mineral raised in all the above-named mines during the past year.

Summary No. 3 contains an account of fatal accidents and lives lost during the year 1876 in and about all the mines coming within the scope of the Coal Mines Regulation Act. The fatal accidents amounted to 839, and the deaths occasioned thereby reached 933; showing a decrease (when compared with the summary of 1875) of 88 in the number of fatal accidents, and 311 in the number of lives lost.

No. 4, the last of the summaries classed under the said Act, show the proportion which the accidents

and deaths bear to the number of persons employed and the quantity of minerals raised. It appears that on the average during the year under review there was one fatal accident amongst every 613 persons employed in and about the mines, and one death by accident amongst every 551 persons employed; and that for each fatal accident 177,580 tons of mineral were got, and 159,688 tons for each death by accident. During the year 1875, of every 578 persons employed there was one fatal accident, and for every death by accident 430 persons were employed. For the year 1876 one accident has to be recorded for every 613 persons employed, and one death for every 551 persons employed. In 1875 the smaller quantity of 159,331 tons of mineral were wrought per accident, and the small quantity of 118,730 tons per death.

In giving a synopsis of the summaries, and after making comparison with those of the preceding year, it should be stated that, whilst the returns show a diminution in the number of persons employed, there was also a decrease of 116 mines at work, and that the quantity of mineral raised exceeds that of 1875 by 1,289,072 tons.

No. 1.—Summary of Persons Employed in and about the Mines, and Tons

Names of Districts and Inspectors	Underground					Above-			
	Male Persons—Ages					10 to 13		13 to 16	
	10 to 12	12 to 13	13 to 16	Above 16	Total	Males	Females	Males	Females
NEWCASTLE: James Willis									
Cumberland . . .	—	54	423	3,924	4,401	6	—	94	12
Durham, North . . .	—	313	1,750	12,676	14,739	149	—	491	—
Northumberland . .	—	430	2,119	16,947	19,496	52	—	439	—
DURHAM: Thomas Bell									
Durham, South . . .	—	1,257	5,296	39,799	46,352	371	—	1,348	—
Westmoreland . . .	—	—	—	13	13	—	—	—	—
Yorkshire, North Riding .	—	60	467	7,283	7,810	25	—	158	—
MANCHESTER: Jos. Dickinson									
Lancashire, North and East	158	678	2,848	21,364	25,048	128	—	274	23
Ireland	—	—	45	901	946	—	—	8	1
LIVERPOOL: Henry Hall									
Anglesey	—	—	1	11	12	—	—	—	—
Denbighshire . . .	—	136	744	5,067	5,947	9	—	88	17
Flintshire . . .	—	—	284	3,188	3,472	2	—	82	—
Lancashire, West . .	7	572	2,306	20,345	23,230	60	1	432	185
YORKSHIRE: Frank N. Wardell									
Yorkshire, East and West Ridings	398	1,334	6,643	39,992	48,367	226	5	751	6
Lincolnshire (ironstone) .	—	1	7	106	114	3	—	4	—
MIDLAND: Thomas Evans									
Derbyshire	—	431	2,862	19,785	23,078	125	—	551	—
Leicestershire . . .	—	33	398	3,004	3,435	14	—	74	—
Nottinghamshire . .	—	152	1,228	8,914	10,224	37	—	202	—
Warwickshire . . .	—	36	339	3,078	3,453	5	—	81	—
STAFFORDSHIRE, N.: Thos. Wynne									
Cheshire	—	41	170	1,728	1,939	24	—	41	—
Shropshire	—	70	594	4,020	4,684	3	—	57	127
Staffordshire, North . .	—	158	1,433	12,367	13,958	15	—	333	1
STAFFORDSHIRE, S.: J. P. Baker									
Worcestershire and South Staffordshire . . .	—	121	2,403	21,952	24,476	5	—	562	33
SOUTH-WESTERN: Thos. Cadman									
Breconshire (part of) .	—	8	35	532	575	—	—	1	6
Glamorganshire (part of) .	—	59	219	1,708	1,986	2	1	17	1
Gloucestershire—									
Forest of Dean . .	—	80	450	3,042	3,572	6	—	85	—
Bristol District . .	—	—	239	2,279	2,518	—	—	71	—
Monmouthshire . . .	—	539	1,309	13,436	15,284	6	—	170	39
Somersetshire . . .	—	155	376	3,100	3,631	4	—	63	—
WALES, SOUTH: Thos. E. Wales									
Breconshire (part of) .	—	2	53	478	533	—	—	8	—
Carmarthen . . .	—	40	252	2,097	2,389	2	—	43	1
Glamorganshire (part of) .	—	1,109	3,311	30,810	35,230	14	1	344	27
Pembroke	—	46	112	492	650	—	—	7	2
SCOTLAND, EAST: Ralph Moore									
Coal and Fireclay . .	—	337	3,356	25,072	28,765	3	—	329	73
Ironstone	—	48	497	3,231	3,776	4	2	24	4
Shale	—	2	128	952	1,082	—	—	8	—
SCOTLAND, WEST: W. Alexander									
Coal	2	269	1,774	14,297	16,342	5	—	208	9
Ironstone	—	84	692	6,588	7,364	—	—	79	13
Fireclay, shale, &c. . .	—	—	12	256	268	—	—	—	—
Totals, Gt. Britain & Ireland	565	8,655	45,175	354,834	409,229	1,305	10	7,527	580

a includes alum shale 4,500, and copperas lumps 86.
b includes pyrites 1,045, and alum shale 18.

of Mining Produce, in Great Britain and Ireland, in the Year 1876.

ground—Ages							
Above 16			Total above and below ground	Coal	Fireclay	Ironstone	Shale, &c.
Females	Males	Total		Tons	Tons	Tons	Tons
311	1,200	1,623	6,024	1,392,046	46,248	—	—
2	3,346	3,988	18,727	6,174,147	243,914	—	—
2	4,014	4,507	24,003	6,568,911	120,963	11,552	—
8	10,286	12,913	58,365	19,511,036	408,795	—	—
—	2	2	15	2,020	—	—	—
—	1,858	2,041	9,851	7,867	—	6,564,101	—
143	4,766	5,334	30,382	8,364,179	83,584	—	*a* 4,586
3	407	419	1,365	125,195	3,070	—	—
—	7	7	19	1,820	—	—	—
76	1,307	1,497	7,444	1,560,888	41,777	19,861	—
8	954	1,046	4,518	855,257	7,479	1,165	1,900
1,157	5,128	6,963	30,193	9,091,374	4,915	1,178	—
13	11,649	12,650	61,017	15,129,506	183,234	240,116	—
—	123	130	244	—	—	154,287	—
—	5,832	6,508	29,586	6,959,101	10,807	64,247	—
—	1,057	4,145	4,580	893,204	25,751	66	—
—	3,072	3,311	13,605	3,582,995	—	11,566	—
—	1,038	1,124	4,577	896,246	10,508	45,500	*b* 1,063
—	634	699	2,638	594,300	5,000	—	*c* 46,500
739	970	1,896	6,580	1,059,740	73,500	425,600	*d* 560
7	4,247	4,603	18,561	3,905,066	5,000	1,443,130	*e* 13,305
924	6,798	8,322	32,798	10,000,000	191,879	294,842	*f* 390
50	50	107	682	53,913	2,528	30,052	*g* 3,259
41	308	370	2,356	755,503	5,013	353	*h* 1,000
—	770	861	4,433	619,805	—	—	—
—	536	607	3,125	541,853	—	294	—
540	2,087	2,842	18,126	4,499,421	92,987	110,684	*k* 14,910
—	824	891	4,522	650,714	1,422	1,362	*l* 3,003
9	64	81	614	75,883	—	8,135	—
27	644	717	3,106	554,602	28,000	5,634	—
520	5,542	6,448	41,678	10,953,241	118,668	168,528	—
124	138	271	921	79,721	—	—	—
552	5,182	6,139	34,904	11,667,648	146,837	—	—
111	726	871	4,647	—	—	836,873	—
1	190	199	1,281	—	—	—	454,892
48	3,024	3,294	19,636	6,997,964	—	—	—
49	1,593	1,734	9,098	—	—	1,710,454	—
—	43	43	311	—	210,104	—	*m* 87,288
5,465	90,416	105,303	514,532	134,125,166	2,071,983	12,159,580	632,656

c, d, e, mixed with cannel.
g, h, k, i, building stone.

f, pyrites.
m, includes pyrites 907.

No. 2.—Summary of Mining Produce, under the Coal Mines Regulation Act, in Great Britain and Ireland in the Year 1876.

COAL.

	Inspector	Tons	Total tons
ENGLAND AND WALES:			
Anglesey	H. Hall . . .	—	1,820
Brecconshire (part of) . . .	T. Cadman . .	53,913	
Do.	T. E. Wales . .	75,883	
			129,796
Carmarthen	T. E. Wales . .	—	554,602
Cheshire	T. Wynne . .	—	594,300
Cumberland	J. Willis . . .	—	1,392,046
Denbighshire	H. Hall . . .	—	1,560,888
Derbyshire	T. Evans . .	—	6,959,191
Durham, North	J. Willis . . .	6,174,147	
Do. South	T. Bell . . .	19,511,036	
			25,685,183
Flintshire	H. Hall . . .	—	855,257
Glamorganshire (part of) . .	T. Cadman . .	755,503	
Do	T. E. Wales . .	10,953,241	
			11,708,744
Gloucestershire, Bristol . .	T. Cadman . .	541,853	
Do. Forest of Dean .	Do. . . .	619,805	
			1,161,658
Lancashire, North and East .	J. Dickinson . .	8,364,179	
Do. West	H. Hall . . .	9,091,374	
			17,455,553
Leicestershire	T. Evans . .	—	893,204
Monmouthshire	T. Cadman . .	—	4,499,421
Northumberland	J. Willis . . .	—	6,568,911
Nottinghamshire	T. Evans . . .	—	3,582,995
Pembrokeshire	T. E. Wales . .	—	79,721
Shropshire	T. Wynne . .	—	1,059,740
Somersetshire	T. Cadman . .	—	650,714
Staffordshire, North . . .	T. Wynne . .	3,905,066	
Do. South . . .	J. P. Baker . }	10,000,000	
Worcestershire	Do. . . }		
			13,905,066
Warwickshire	T. Evans . . .	—	896,246
Westmoreland	T. Bell . . .	—	2,020
Yorkshire, East and West Ridings	F. N. Wardell .	15,129,506	
Do. North Riding . .	T. Bell . . .	7,867	
			15,137,373
Total produce of coal in England and Wales .		. . .	115,334,359
SCOTLAND:			
Argyle and Dumfries . .	W. Alexander .	—	97,139
Ayrshire	Do. . .	—	3,649,991
Clackmannan, Kinross, Perth, and Sutherland . . }	R. Moore . .	—	260,845
Dumfries (see Argyle) . .	W. Alexander . .		
Dumbarton	Do. . .	—	175,138
Edinburgh	R. Moore . .	—	715,803
Fife	Do. . . .	—	1,688,410
Haddington	Do. . . .	—	225,031
Kingross (see Clackmannan) .	Do. . . .		
Lanark, East	Do. . . .	7,665,117	
Do. West	W. Alexander. .	2,653,317	
			10,318,434

Summary of Mining Produce—Continued.

	Inspector	Tons	Total Tons
Brought forward	. . .	. . .	10,318,434
Linlithgow	R. Moore	—	368,911
Perth (see Clackmannan)	Do.		
Renfrew	W. Alexander	—	157,141
Stirling, West	Do.	265,238	
Do. East	R. Moore	743,531	
			1,008,769
Sutherland (see Clackmannan)	Do.		
Total produce of Coal in Scotland		. . .	18,665,612
IRELAND:			
Connaught	J. Dickinson	—	5,203
Leinster	Do.	—	75,025
Munster	Do.	—	32,632
Ulster	Do.	—	15,335
Total produce of Coal in Ireland		. . .	125,195
Total produce of Coal in Great Britain and Ireland			134,125,166

FIRECLAY.

ENGLAND AND WALES:			
Breconshire (part of)	T. Cadman	—	2,528
Carmarthen	T. E. Wales	—	28,000
Cheshire	T. Wynne	—	5,000
Cumberland	J. Willis	—	46,248
Denbighshire	H. Hall	—	41,777
Derbyshire	T. Evans	—	10,807
Durham, North	J. Willis	243,914	
Do. South	T. Bell	408,795	
			652,709
Flintshire	H. Hall	—	7,479
Glamorganshire (part of)	T. Cadman	5,013	
Do.	T. E. Wales	118,668	
			123,681
Lancashire, North and East	J. Dickinson	83,584	
Do. West	H. Hall	4,915	
			88,499
Leicestershire	T. Evans	—	25,751
Monmouthshire	T. Cadman	—	92,987
Northumberland	J. Willis	—	120,963
Shropshire	T. Wynne	—	73,500
Somersetshire	T. Cadman	—	1,422
Staffordshire, North	T. Wynne	5,000	
Do. South, and Worcestershire	J. P. Baker	191,879	
			196,879
Warwickshire	T. Evans	—	10,508
Yorkshire, East and West Ridings	F. N. Wardell	—	183,234
Total produce of Fireclay in England and Wales			1,711,972

Summary of Mining Produce—Continued.

	Inspector	Tons	Total Tons
Brought forward . .	. . . . . .	. . .	1,711,972
SCOTLAND:			
Ayrshire	W. Alexander . .	—	90,336
Clackmannan, Perth . . .	R. Moore . .	—	3,679
Edinburgh	Do. . . .	—	25,172
Fife	Do. . . .	—	12,327
Haddington	Do. . . .	—	11,967
Lanark East	Do. . . .	85,306	
Do. West	W. Alexander . .	94,243	
			179,549
Linlithgow	R. Moore . .	—	3,392
Perth (see Clackmannan) . .	Do.		
Renfrew	W. Alexander .	—	25,525
Stirling, East	R. Moore . .	—	4,994
Total produce of Fireclay in Scotland		. . .	356,941
IRELAND:			
Connaught	J. Dickinson		
Leinster	Do.		
Munster	Do.		
Ulster	Do. . . .	—	3,070
Total produce of Fireclay in Ireland		. . .	3,070
Total produce of Fireclay in Great Britain and Ireland .			2,071,983

IRONSTONE.

	Inspector	Tons	Total Tons
ENGLAND AND WALES:			
Brecconshire (part of) . . .	T. Cadman . .	30,052	
Do.	T. E. Wales . .	8,135	
			38,187
Carmarthen	Do. . . .	—	15,634
Denbighshire	H. Hall . . .	—	19,861
Derbyshire	T. Evans . .	—	64,247
Flintshire	H. Hall . . .	—	1,165
Glamorganshire (part of) . .	T. Cadman . .	353	
Do	T. E. Wales . .	168,528	
			168,881
Gloucester, Bristol District .	T. Cadman . .	—	294
Lancashire, West	H. Hall . . .	—	1,178
Leicestershire	T. Evans . .	—	66
Lincolnshire (exclusive of open work)	F. N. Wardell . .	—	154,287
Monmouthshire	T. Cadman . .	—	110,684
Northumberland	J. Willis . . .	—	11,552
Nottinghamshire	T. Evans . .	—	11,566
Shropshire	T. Wynne . .	—	425,600
Somersetshire	T. Cadman . .	—	1,362
Staffordshire, North . . .	T. Wynne . .	1,443,130	
Do. South, and Worcestershire . . .	J. P. Baker . .	294,842	
			1,737,972
Warwickshire	T. Evans . .	—	45,500
Yorkshire, East and West Ridings	F. N. Wardell . .	240,116	
Do. Cleveland . . .	T. Bell . , .	6,564,101	
			6,804,217
Total produce of Ironstone in England and Wales .			9,612,253

Summary of Mining Produce—Continued.

	Inspector	Tons	Total Tons
Brought forward . .	. . . . .	. . .	9,612,253
SCOTLAND:			
Ayrshire	W. Alexander .	—	860,648
Dumbarton	Do. . . .	—	249,637
Edinburgh	R. Moore . .	—	61,262
Fife	Do. . . .	—	14,274
Haddington	Do. . . .	—	6,224
Kinross and Perth . . .	Do. . . .	—	41,100
Lanark (part of)	Do. . . .	527,146	
Do. (part of)	W. Alexander .	252,117	
			779,263
Linlithgow	R. Moore . .	—	186,460
Perth (see Kinross) . . .	Do.		
Renfrew	W. Alexander . .	—	185,678
Stirling (part of)	R. Moore . .	407	
Do. Do.	W. Alexander .	162,374	
			162,781
Total produce of Ironstone in Scotland . .			2,547,327
IRELAND:			
Connaught	—	—	None
Leinster	—	—	"
Munster	—	—	"
Ulster	—	—	"
Total produce of Ironstone in Great Britain .			12,159,580

SHALE.

ENGLAND AND WALES:			
Cheshire (mixed with cannel) .	T. Wynne . .	—	46,500
Flintshire	H. Hall . . .	—	1,900
Shropshire (mixed with cannel) .	T. Wynne . .	—	560
Staffordshire, North (mixed with cannel) . . .	Do. . . .	—	13,305
Total produce of Shale in England and Wales .			62,265
SCOTLAND:			
Ayrshire	W. Alexander . .	—	9,074
Edinburgh	R. Moore . .	—	258,278
Fife	Do. . . .	—	2,000
Lanark (part of)	Do. . . .	28,813	
Do. Do.	W. Alexander .	364	
			29,177
Linlithgow	R. Moore . .	—	161,832
Renfrew	W. Alexander . .	—	76,943
Stirling (part of)	R. Moore . .	—	3,969
Total produce of Shale in Scotland .			541,273
IRELAND			None
Total produce of Shale in Great Britain . .			603,538

Summary of Mining Produce—Continued.

ALUM SHALE.

	Inspector	Tons	Total Tons
ENGLAND:			
Lancashire, North and East .	J. Dickinson . .	—	4,500
Warwickshire	T. Evans . .	—	18
Total produce of Alum Shale in England .			4,518
SCOTLAND			None
IRELAND			None

PYRITES OR COPPERAS LUMPS.

	Inspector	Tons	Total Tons
ENGLAND:			
Lancashire, North and East .	J. Dickinson . .	—	86
Staffordshire, South, and Worcestershire . . .	J. P. Baker . .	—	390
Warwickshire	T. Evans . .	—	1,045
Total Pyrites or Copperas Lumps in England .			1,521
SCOTLAND			
Dumbarton	W. Alexander .	—	577
Renfrew	Do. . .	—	330
Total Pyrites or Copperas Lumps in Scotland .			907
Total Pyrites or Copperas Lumps in Great Britain			2,428

BUILDING STONE.

	Inspector	Tons	Total Tons
ENGLAND AND WALES:			
Breconshire	T. Cadman . .	—	3,259
Glamorganshire (part of) . .	Do.	—	1,000
Monmouth	Do.	—	14,910
Somerset	Do.	—	3,003
Total produce of Building Stone in England and Wales			22,172
Total produce of Shale, &c. in Great Britain . .			632,656

and Ireland during the Year 1876.

Names of Districts	Explosions of Firedamp	Falls in Mine: Falls of Side	Falls of Roof	Total Falls in Mine	In Shafts: Overwinding	Ropes and Chains Breaking	Whilst ascending or descending by Machinery	Falling into Shaft from Surface	Things falling from Surface	Falling from part way down	Things falling from part way down	Miscellaneous in Shafts	Total in Shafts	Miscellaneous Underground: Explosions of Gunpowder, &c.	Suffocation by Gases	Irruptions of Water	Falling into Water	On Inclined Planes	By Trams and Tubs	By Machinery Underground	Sundries Underground	Total Miscellaneous Underground	On Surface: By Machinery on Surface	Boilers Bursting	Miscellaneous on Surface	Total on Surface	Gross Total
Northumberland, Cumberland, and North Durham	2	6	28	34	—	—	—	—	—	2	1	2	5	1	—	—	—	2	14	—	1	18	1	1	6	8	67
South Durham and Westmoreland	2	6	36	42	—	—	—	1	—	2	1	1	5	1	—	—	—	5	7	—	2	15	2	—	9	11	75
Yorkshire, North Riding	1	5	2	7	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	3	1	—	4	5	16
North and East Lancashire	3	6	16	22	—	—	2	—	2	—	—	1	5	—	—	1	—	4	4	—	—	9	2	—	3	5	44
Ireland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Lancashire and North Wales	11	17	43	60	—	1	2	1	2	4	3	3	16	4	—	—	—	5	4	—	3	16	3	—	9	12	115
Yorkshire	3	14	21	35	1	—	2	2	—	—	2	2	9	—	—	—	—	2	4	1	1	8	2	—	12	14	69
Do. (ironstone)	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Lincolnshire (ironstone)	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Derby, Nottingham, Leicester, and Warwickshire	1	13	28	41	1	—	3	1	—	1	1	—	7	2	—	—	—	4	7	—	—	13	3	—	1	4	66
Do. (ironstone and fireclay)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
North Stafford, Cheshire, and Shropshire	3	7	10	17	—	—	3	1	—	1	—	3	8	—	—	—	—	7	3	—	—	10	1	—	3	4	42
Do. (ironstone)	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	1	1	4
South Stafford and Worcestershire	4	18	13	31	—	—	2	1	—	—	4	8	15	5	—	—	—	—	5	—	3	13	5	—	4	9	72
Do. (ironstone and fireclay)	—	1	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Monmouth, Gloucester, Somerset, and Devon	4	3	25	28	—	1	—	1	2	2	—	—	6	—	1	—	—	1	2	—	—	4	—	—	5	5	47
Do. (ironstone)	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
South Wales	3	12	39	51	—	—	2	3	—	4	6	4	19	2	2	—	—	12	8	—	1	25	—	—	13	13	111
Do. (ironstone, &c.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scotland (East)	1	9	24	33	—	1	—	5	1	2	1	2	12	—	—	—	—	5	2	—	1	8	2	1	3	6	60
Do. (ironstone, &c.)	—	1	2	3	—	—	1	—	1	2	—	—	4	—	—	—	—	1	—	—	—	1	—	—	—	—	8
Scotland (West)	4	3	15	18	—	—	1	1	—	1	—	2	5	—	—	—	—	—	1	—	—	1	1	—	1	3	31
Do. (ironstone, &c.)	—	—	2	2	—	—	—	1	—	2	—	—	3	1	—	—	—	—	—	—	—	1	1	—	—	1	7
Total in 1876	42	121	309	430	2	3	18	19	8	23	19	28	120	16	3	1	—	50	61	1	14	146	24	3	74	101	839
Ditto in the preceding year	41	123	316	439	2	4	33	18	12	31	22	31	153	18	13	3	—	38	88	7	29	196	16	3	79	98	927

No. 3.—Summary of Deaths caused by the aforesaid Accidents in and about the Coal, Fireclay, Ironstone, and Shale Mines of Great Britain and Ireland during the Year 1876.

		Falls in Mine			In Shafts									Miscellaneous Underground									On Surface				
Names of Districts	Explosions of Firedamp	Falls of Side	Falls of Roof	Total Falls in Mine	Overwinding	Ropes and Chains Breaking	Whilst ascending or descending by Machinery	Falling into Shaft from Surface	Things falling from Surface	Falling from part way down	Things falling from part way down	Miscellaneous in Shafts	Total in Shafts	Explosions of Gunpowder, &c.	Suffocation by Gases	Irruptions of Water	Falling into Water	On Inclined Planes	By Trams and Tubs	By Machinery Underground	Sundries Underground	Total Miscellaneous Underground	By Machinery on Sursace	Boilers bursting	Miscellaneous on Surface	Total on Surface	Gross Total
Northumberland, Cumberland, and North Durham	3	6	29	35	—	—	—	—	—	2	1	2	5	1	—	—	—	2	14	—	1	18	1	2	6	9	70
South Durham and Westmoreland	5	6	36	42	—	—	—	1	—	2	1	1	5	1	—	—	—	5	7	—	2	15	2	—	9	11	78
Yorkshire, North Riding	1	5	2	7	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	2	3	1	—	4	5	16
North and East Lancashire	5	6	18	24	—	—	2	—	4	—	—	1	7	—	—	2	—	4	4	—	—	10	2	—	3	5	51
Ireland	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
West Lancashire and North Wales	14	17	44	61	—	1	4	1	2	4	3	3	18	4	—	—	—	5	4	1	3	16	3	—	9	12	121
Yorkshire	3	14	21	35	1	—	2	2	—	—	2	2	9	—	—	—	—	2	4	—	1	8	2	—	12	14	69
Do. (ironstone)	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Lincolnshire (ironstone)	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Derby, Nottingham, Leicester, and Warwickshire	6	13	33	46	2	—	3	1	—	1	1	—	8	2	—	—	—	4	7	—	—	13	3	—	1	4	77
Do. (ironstone and fireclay)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
North Stafford, Cheshire, and Shropshire	11	7	10	17	—	—	3	1	—	1	—	3	8	—	—	—	—	8	3	—	—	11	1	—	4	5	52
Do. (ironstone)	—	—	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—	1	1	4
South Stafford and Worcestershire	5	18	15	33	—	—	2	1	—	—	4	11	18	5	—	—	—	—	5	—	3	13	5	—	4	9	78
Do. (ironstone and fireclay)	—	1	—	1	—	—	—	1	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Monmouth, Gloucester, Somerset, and Devon	29	3	26	29	—	1	—	1	2	2	—	—	6	—	1	—	—	1	2	—	—	4	—	—	5	5	73
Do. (ironstone)	—	—	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
South Wales	4	12	42	54	—	—	2	3	—	4	7	4	20	2	2	—	—	12	8	—	1	25	—	—	14	14	117
Do. (ironstone)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scotland (East)	2	9	26	35	—	1	—	5	1	2	1	2	12	—	—	—	—	5	2	—	1	8	2	5	6	13	70
Do. (ironstone, &c.)	—	1	2	3	—	—	1	—	1	2	—	—	4	—	—	—	—	1	—	—	—	1	—	—	—	—	8
Scotland (West)	7	4	16	20	—	—	1	1	—	1	—	2	5	—	—	—	—	—	1	—	—	1	1	1	1	3	36
Do. (ironstone, &c.)	—	—	2	2	—	—	—	1	—	2	—	—	3	2	—	—	—	—	—	—	—	2	1	—	—	1	8
Total in 1876	95	122	327	449	3	3	20	19	10	23	20	31	129	17	3	2	—	51	61	1	14	149	24	8	79	111	933
Ditto in the preceding year	288	127	331	458	4	6	41	18	13	33	23	34	172	22	32	8	—	38	88	9	30	227	16	3	80	99	1244

No. 4.—Summary showing the Proportion of Accidents and Lives Lost to the Number of Persons Employed in and about the Mines, and the Quantity of Minerals Wrought in Great Britain and Ireland during the Year 1876.

Names of Districts	Persons employed in and about the Mines	Tons of Mineral Wrought: Coal	Fireclay	Ironstone	Shale, &c.	Total	Separate Fatal Accidents	Lives lost by the Accidents	Persons employed: Per Fatal Accident	Per Life Lost	Tons of Mineral wrought: Per Fatal Accident	Per Life Lost	Number of Mines
Northumberland, Cumberland, and North Durham	48,754	14,135,104	411,125	11,552	—	14,557,781	67	70	728	696	218,773	207,968	218
South Durham and Westmoreland, and North Riding of Yorkshire	58,380	19,513,056	408,795	—	—	19,921,851	75	78	778	748	265,625	255,408	212
Yorkshire—Cleveland (ironstone)	9,851	7,867	—	6,564,101	—	6,571,968	16	16	616	616	410,748	419,748	46
North and East Lancashire	30,382	8,364,179	83,584	—	4,586	8,452,349	44	51	690	595	192,098	165,732	371
Ireland	1,365	125,195	3,070	—	—	128,265	—	—	—	—	—	—	39
West Lancashire and North Wales	42,174	11,509,339	54,171	22,204	1,900	11,587,614	115	121	366	348	100,762	95,765	312
Yorkshire	61,017	15,129,506	183,234	240,116	—	15,552,856	70	70	872	872	222,184	222,184	539
Lincolnshire (ironstone)	244	—	—	154,287	—	154,287	1	1	244	244	154,287	154,287	10
Derbyshire, Leicestershire, Nottingham, and Warwickshire	52,348	12,331,546	47,066	121,379	1,063	12,501,054	66	77	793	679	189,394	162,338	419
North Stafford, Cheshire, and Shropshire	27,779	5,559,106	83,500	1,868,730	60,365	7,571,701	46	56	603	496	164,600	135,207	250
South Staffordshire and Worcestershire	32,798	10,000,000	191,879	294,842	390	10,487,111	74	80	443	410	141,718	131,089	509
Monmouth, Somerset, part of Glamorgan, and Breconshire	33,244	7,121,209	101,950	142,745	22,172	7,388,076	48	74	692	449	153,918	99,838	415
South Wales	46,319	11,663,447	146,668	192,297	—	12,002,412	111	117	418	396	108,130	102,584	335
Scotland, East	40,832	11,667,648	146,837	836,873	454,892	13,106,250	68	78	600	523	192,739	168,029	367
Scotland, West	29,045	6,997,964	210,104	1,710,454	87,288	9,005,810	38	44	764	660	236,995	204,677	343
Totals and averages	514,532	134,125,166	2,071,983	12,159,580	632,656	148,989,385	839	933	613	551	177,580	159,688	4,385

The following is a table of the deepest mines and borings in Great Britain at the present time:—

No.	Colliery	County	Mineral worked	Depth in yards
1	Rosebridge	Lancashire	Coal	815
*2	Dukenfield	,, ...	,,	686
3	Monkwearmouth . . .	Durham	,,	580
4	Pendleton	Lancashire	,,	526
5	Sharlston	Yorkshire	,,	512
6	Shire Oaks	Nottinghamshire . .	,,	510
7	Annesley	,, ...	,,	504
8	Ince Hall	Lancashire	,,	600
9	Douglas Bank	,, ...	,,	525
10	Lindsey	,, ...	,,	505
11	Worthington	,, ...	,,	600
12	Seaham	Durham	,,	508
13	Ryhope	,, ...	,,	542

* Reached by incline a total depth of 940 yards from the surface.

As Monkwearmouth seems to have been the pioneer of deep mining in this country it deserves a passing reference to its history. The sinking of the colliery commenced in the year 1826, and continued for nine years, struggling with great engineering difficulties, without meeting with any material success. The enterprising spirit of the owners was not encouraged at that time by colliery managers generally, some of whom predicted that, owing to the fact of the Permian rocks overlying that portion of the country, the coal measures there would be found either absent or unworkable—an opinion that a very moderate amount of geological knowledge would have shown to be without foundation. The shaft was continued down to a depth of forty-six yards, when the water found in the limestone stopped operations for a while. The second shaft was then com-

menced, which reached, at a depth of 360 yards, in the year 1835, the Maudlin Seam, which was found of an inferior quality. The sinking of the first shaft was resumed in 1841 and continued to a depth of 160 yards, from which point a drift was driven to the coal reached in the second shaft. The seam of coal referred to was then worked for some years, after which the Hutton Seam was sunk to, and reached in 1869, at the depth of 550 yards.

No.	Name of boring	Situation	Country	Depth in yards
1	Artesian Spring	Potsdam	Missouri	1,833
2	Rock Salt Bore-hole	Sperenberg	Near Berlin, Prussia	1,392
3	Boring for coal	Creusiton	France	1,007
4	Boring in progress for coal, reached up to the present time	Scarle, near Lincoln	England	700
5	Boring for minerals by the Eden Valley Mining Company	Eden Valley, Cumberland	England	766
6	Swinderby	Near Lincoln	England	666
7	Sub-Wealden	Suffolk	England	635
8	Artesian Well	Gunelle, near Paris	France	599

No.	Country	Name of Mine	District	Mineral Worked	Depth in yards
1	Austria	Adalbert	Prizibram	Silver and lead	1,093
2	Belgium	Viviers	Gilly	Coal	940
3	Saxony	—	Zwickaw	Coal	879
4	Prussia	Samon	St. Andre	Silver	844
5	Gt. Britain	Rosebridge	Wigan	Coal	814
6	Norway	—	Konsberg	Silver	623
7	Hungary	Amalia	Schmeritz	Gold and silver	590
8	Prussia	Camphausen	Saarbruck	Coal	550
9	Spain	La 'Luerti	Canada	Silver	516
10	Italy	Monte Masio	Gavarrono	Lignite	481
11	Sweden	Bersbo	—	Copper	459
12	Pays-bas	Whilhelm	Kerkrade	Coal	364
13	Baden	—	Hagenbruck	Coal	360
14	Portugal	Taylor	Pallial	Copper	359
15	Bavaria	Max	Stockholm	Coal	286
16	Russia	Turjinsk	—	Copper	202

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